IMPROVING THE QUALITY OF LIFE FOR OLDER ADULTS IN HIGH-RISE RESIDENTIAL BUILDINGS IN URBAN HONOLULU THROUGH RESPONSIVE AND ADAPTIVE DESIGN

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Abstract

Hawai‘i's housing crisis and high cost of living affect quality of life for its residents, particularly the older adult population. Consequently, many older adults end up living in unfit environments. As Hawai‘i's overall population grows and ages, these challenges escalate in size and complexity. Moreover, as the earth’s climate continues to change, the impacts of the built space intensify, putting this already vulnerable population at even greater risk.

This research proposes an architectural design criterion for improving the quality of life of older adults that is based on combined design solutions explored through several case studies. These design solutions include adaptive design, which adjusts the living environment to the demographic, social, and cultural contexts; bioclimatic design, which focuses on comfort in response to changing climate conditions; and lastly, biophilic design, which embraces the relationship between humans and nature in architecture.

The last portion of the research proposes an architectural design for a high-rise residence that employs the design criteria and includes adaptive and bioclimatic features. Indoor comfort was assessed using building simulation software to determine the effectiveness of the proposed design methods. The overall healthiness of the building was evaluated using five elements derived from Blue Zone communities, as defined by Dan Beuttner,

which were translated into environmental characteristics that measure the overall design of the architecture in relation to human health.

The ultimate goal of this research is to enhance the quality of life for older adults in a residential high-rise typology, the architectural prototype will serve as inspiration for an alternative option of dwelling for Hawaiʻi's older adult population that addresses the evolution of life and specifically supports the residents' well-being

Table of Contents

Abstract ii

1. Introduction 3

Research Objective 5

2. Growing and Aging Population 6

   2.1 Population in the U.S 6

   2.2 Population of Hawai'i 7

   2.3 Life Expectancy in Hawai'i 9

3. Being Healthy 11

   3.1 Social Determinants 12

   3.2 Built Environment 13

4. Health and the Indoor Environment 14

   4.1 Impacts of Various Characteristics of Housing 15

5. Global Warming 20

6. Current Housing Options for Seniors in Hawai'i 23

7. Hawai'i's Affordable Housing Crisis 26

8. Multigenerational Housing 26

9. The need for High-rise Buildings 45

   9.1 Challenges in High-rise buildings 45

10. Design Criterion 50

11. Adaptive Design 53

   11.1 Multigenerational Household 53

12. Bioclimatic 85

12.1 Bioclimatic High-rise 92

12.2 Responsive Design Process 95

12.3 Designing for Hawaiʻi 105

12.4 Thermal Comfort 100

13. Biophilic Design 125

14. Design Criteria Evaluation 140

14.1 Blue Zones 141

14.2 Interrelation 145

15. Conclusion 263

Bibliography 271

List of Figures

Figure 1: Population Density per Square Mile Oahu 8
Figure 2: Population Density per Square Mile, the rest of State 8
Figure 3: Aging Population in Hawaiʻi 9
Figure 4: Excess mortality distribution of sex, age, and setting. France 2003. Poumadere et al. 22
Figure 5: Population living alone and dependency level 34
Figure 6: Comparison of Multigenerational Households to the Ohana Zone. Source: U.S. Census 40
Figure 7: Design Principles 53
Figure 8: Horizontal addition 60
Figure 9: Vertical addition 60
Figure 10: Slack spaces 60
Figure 11: Neutral spaces 62
Figure 12: Circulations 62
Figure 13: Joining rooms or units 62
Figure 14: Joining and dividing units 62
Figure 15: Multiple entrances 62
Figure 16: Shared rooms 62
Figure 17: Connection between rooms 64
Figure 18: Collapsible furniture 64
Figure 19: Operable walls 64
Figure 20: Disassembly 66
Figure 21: Clear spans 66
Figure 22: Partitions 66
Figure 23: Horizontal services 66
Figure 24: Vertical services 66
Figure 25: Songpa Micro Housing 70

Figure 26: Corridors transformation of function 71
Figure 27: Flexible components 72
Figure 28: A House With 3 Walls 73
Figure 29: First and Second Floor Plan 74
Figure 30: Adaptability overtime 75
Figure 31: Seasonal flexibility 75
Figure 32: Raku-inkyo A existing 76
Figure 33: Raku-inkyo B existing 76
Figure 34: Raku-inkyo A and B Existing floor plans 77
Figure 35: Raku-Inkyo C Plan 78
Figure 36: Infill systems 79
Figure 37: Folding partition 80
Figure 38: Multigenerational Housing Development in Freiburg, Germany81
Figure 39: Light construction walls and plumbing location 82
Figure 40: Diverse unit types 83
Figure 41: Via Verde Housing Development 83
Figure 42: 2 Bedroom complex 84
Figure 43: 2 and 3 Bedroom complex 85
Figure 44: Bioclimatic Chart, for U.S. Moderate Climate Zone 102
Figure 45: Bioclimatic Chart, Hawaii Climate Conditions 105
Figure 46: Hawai'i Temperature Range 106
Figure 47: Hawai'i Wind Rose 108
Figure 48: Menara Mesiniaga, Malaysia, Ken Yeang 109
Figure 49: Desing Concept Sketch 110
Figure 50: Sky Garden Diagram 110
Figure 51: Sun Shades Diagram 110
Figure 52 A & B: Shading Device Detail 111
Figure 53: Federal Building, San Francisco, Morphosis 112
Figure 54: Skip Stop Elevator 113

Figure 55: Cross ventilation Diagram 113
Figure 56: Air Space Above Central Offices 113
Figure 57: CFD Simulation 113
Figure 58: City Council House 2, Melbourne, DesignInc 114
Figure 59: Daytime and Night time Bioclimatic Strategies 115
Figure 60: Newton Suites, Singapore, WOHA 116
Figure 61: Building Shading Device 117
Figure 62: Building Section; Lanai Sky Gardens 117
Figure 63: Moulmein Rise, Singapore, WOHA 118
Figure 64: Pixelated Building Screen 119
Figure 65: Bay Window; Monsoon Window 120
Figure 66: Penthouse with monsoon windows and high ceiling 120
Figure 67: Operable Bay Window with Monsoon window 120
Figure 68: Bay Window; Monsoon Window with Internal Blinds 120
Figure 69 A & B: Bay Window; Monsoon Window Detail Sections 121
Figure 70: Oasia Hotel Downtown, Singapore 122
Figure 71: Oasia Hotel Downtown Building Section 123
Figure 72 A & B: Sky Gardens 124
Figure 73: PARKROYAL on Pickering 133
Figure 74: Comon Floor Plan 133
Figure 75: View from Guest Room 134
Figure 76: View from Bathroom 134
Figure 77: Interior Finish at Guest Bedroom 135
Figure 78: Interior Finish at Common Room 135
Figure 79: Water features along Corridors 135
Figure 80: Water Features along Lobby Corridors 135
Figure 81: Spiral Staircase 136
Figure 82: Organic Formwork of the Facade and Ceiling 136
Figure 83: lighting at Public Spaces 136

Figure 84: Daylighting and Surface Shadows 136
Figure 85: Openness of the Lobby Spaces 137
Figure 86: Openness of Public Spaces 137
Figure 87: Building Section 138
Figure 88: Blue Zone Power 9 143
Figure 89: Kaka'ako District 153
Figure 90: Transit Oriented Development ¼ mile radius 154
Figure 91: Mapping Diagram of Rail Station and Street Walkability & Pedestrian Prioritized Streets 154
Figure 92: 801 South Street Apartments High-Rise 157
Figure 93: 801 South St. Typical Floor Plan 157
Figure 94: Ke Kilohana Condominium High-Rise 160
Figure 95: Ke Kilohana Typical Floor Plan 160
Figure 96: Site Location and Existing Conditions 166
Figure 97: Site Location in Kaka'ako Master Plan 167
Figure 98: Existing and Proposed Buildings Near Site 167
Figure 99: Daylight Simulation on Site 168
Figure 100: Predominant Wind Direction and Speed for Honolulu, HI 169
Figure 101: Site Wind Flow at 30ft, 60ft & 200ft 170
Figure 102: Building Height Zone, Hawaii Community Development Authority 172
Figure 103: Podium High-Rise Building Typology 173
Figure 104: Designated View Corridors 173
Figure 105: View Corridor Orientation 174
Figure 106: Comparison of Solar Exposure for View Corridor and South Oriented Mass 175
Figure 107: View Corridor Building Mass External Wind Flow Simulation at 30ft, 60ft, and 200ft 177

Figure 108: South Oriented Building Mass External Wind flow at 30ft, 60ft & 200ft.....178
Figure 109: Acceptable operative temperature from naturally conditioned spaces, adding increases of the upper limit resulting from increasing in air speeds. Source: ASHRAE 55-2013. 183
Figure 110: Prototype 1 and simple mass Wind Flow Analysis.....184
Figure 111: Window-to-Wall Ratio and Thermal Comfort, No Shading 188
Figure 112: Surface Solar radiation, with and Without Shading Device.....197
Figure 113: Building Section and Program Zones.....198
Figure 114: Sky Lanai and Skip Stop Circulation and Sky Lanais 200
Figure 115: Sky Lanai Programming 201
Figure 116: Prototype 2 Sky Lanai Perspective Rendering 202
Figure 117: Unit Lanai Layout 1&2.....212
Figure 118: Unit Lanai Layout 3&4.....212
Figure 119: Doorway Minimum Width 214
Figure 120: Bathroom Dimension for Americans with Disabilities (ADA).....214
Figure 121: Bathroom Proper Dimensions.....215
Figure 122: Prototype 1 South-West Elevation 218
Figure 123: Prototype 2 Wind Flow Simulation 221
Figure 124: Window-to-Wall Ratio Comfort Analysis.....224
Figure 125: Horizontal Shading and Orientation Comfort Analysis 226
Figure 126: Fins Shading Device and Orientation Comfort Analysis 227
Figure 127: Louvers Shading Device and Orientation Comfort Analysis.....228
Figure 128: Combined Shading and Orientation Comfort Analysis.....229
Figure 129: Comfort Analysis Overlay for 5ft Overhang, 5ft Fins, 5ft Combined, and 10 Louvers 230
Figure 130: Shading Device Solar Radiation Analysis.....231
Figure 131: Building Section and Programming 233
Figure 132: Prototype 2, Skip-stop Circulation and Sky Lanais.....235

Figure 133: Sky Lanai, Community Spaces..236
Figure 134: Layout 1&2 Unit Lanai..244
Figure 135: Unit 3&4 Unit Lanai 244
Figure 136: Doorway and Opening ADA Dimensions 246
Figure 137: Bathroom Proper Dimensions..246
Figure 138: Prototype 2 Layout 2 Lanai and stairs rendering with the high ceiling view 247
Figure 139: Prototype 2 Layout 2 Exterior view of the stacked units 248
Figure 140: Prototype 2 Layout 1A & 1B Interior Rendering.........................249
Figure 141: Prototype 2 South Elevation 250
Figure 142: Prototype 2 Exterior Rendering of the Sky Lanai 251

List of Tables

Table 1: Life Expectancy at Birth by State 2010. Data collected by Measures of America 10
Table 2: Lot Size to Building Floor Plate Ratio, Hawaii Community Development Authority 172
Table 3: : Increases in Acceptable Operative Temperature Limits in occupant-controlled, naturally conditioned spaces resulting from increasing air speed above 0.3m/s (59 fpm) Source: ASHRAE 55-2013. ...184
Table 4: Family Transformation...204
Table 5: Design Principles Matrix Evaluation...257

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2. Introduction

By 2040, an estimated 23.6% of Hawai‘i’s total population will be 65 years and older, by far the largest of all age groups.[1] In addition, Hawai‘i’s overall population is becoming healthier and leads the nation in life expectancy at 81.3 years.[2] In light of these trends, the state faces the mounting challenges involved in providing appropriate care and services for the growing older adult population, including transportation, personal assistance, education, and medical services, as well as how to help this group maintain good health.[3]

In July 2015, the Department of Health Executive Office on Aging approved the *Hawaii State Plan on Aging*. The plan’s focus was to improve quality of life for older adults for as long as possible.[4] Of the five goals presented, two stand out as most relevant to this research. The first is, “to maximize opportunities for seniors to age well, remain active, and enjoy quality lives while engaging in their communities,” and the second, to optimize “the health, safety, and independence of Hawai‘i’s older adults.”[5]

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[1] “Population and Economic Projections for the State of Hawaii to 2040.” *Research and Economic Analysis Division Department of Business, Economic Development and Tourism.* (HI ,DBEDT 2040 Series. 2012).

[2] Kristen Lewis and S. Burd-Sharps. "American Human Development Report: The Measure of America: 2013–2014." *Social Science Research Council*: Brooklyn, NY. (2015).

[3] State of Hawai’I, “Hawaii State Plan on Aging” October 1, 2015-September 30, 2017 Executive Office on Aging.” Web. accessed on December 14, 2016. http://health.hawaii.gov/eoa/files/2013/07/Hawaii-State-Plan-On-Aging.pdf

[4] Ibid.,1.

[5] Ibid., 2.

While most plans and strategies for achieving these goals focus on improving lifestyle, services, and support,[6] my interest falls instead on the improvement of the physical living environment.

For those who are not home owners, current options for retired living include continuing care retirement communities, standard rental housing units, or accessory dwelling units (ADU). For those who need assistance with daily life, options include nursing homes, residential care homes, and other similar facilities. These options, however, are either very expensive or in high demand, and are often not appropriately developed to cover all the needs of this demographic.[7,8] This is especially true in urban Honolulu where the state's highest concentrations of older adults live.

In response to the lack of senior housing in Honolulu, a number of high-rise residential buildings are being proposed and developed. However, it is unclear whether these buildings will be any better than the problematic already existing high-rise residences,[9] or whether they will improve quality of life for the occupants. This dissertation examines existing buildings and

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[6] Ibid., 6-7.

[7] *Long-Term Care Reform in Hawaii: Report of the Hawaii Long-Term Care Commission Final Report.* Report. Hawaii Long-Term Care Commission. HI, 2012. Accessed December 14, 2016. http://lrbhawaii.info/reports/legrpts/ltcc/act224_4_slh08_final.pdf.

[8] Quester Lau. "Black Boxes and Gray Spaces."

[9] Andrew Warrick, and Asha Rathina Pandi. *Aging in Place: How to Cope A Conference for Condo, Co-op, Townhouse & Apartment Residents, Owners and Managers in Hawaii Conference Report*. Report. Department of Sociology, University of Hawaii. 2003. Accessed December 14, 2016. http://files.hawaii.gov/dcca/reb/condo_ed/condo_gen/condo_pub/condo-conference-reduced-version-1.pdf.

research and proposes an alternative high-rise residential building that offers a living environment that promotes quality of life.

Research Objective

The goal of this research was to develop a design criterion for creating a living environment that promotes quality of life for older adults. The changing climate, which intensifies the impacts of the built environment on the health and comfort of the occupants, was also examined and considered. The criterion was then applied to a high-rise residential building typology to create an alternative for Hawaiʻi's growing retired population, particularly in urban Honolulu. To achieve this, it was necessary to investigate current conditions of the built environment in which this population resides and to identify how these conditions impact physical and psychological health and comfort.

The design criteria was assessed using elements akin to those of Blue Zone communities, or places around the world where people live the longest. The innovation in this assessment comes from the translation of these elements, characteristic of those who live the healthiest lives defined by longevity, into the design of physical space, which in turn will mirror such environments.

3. Growing and Aging Population

3.1 Population in the US

The population of the U.S. increases by about 1.18% every year within the past ten years. The global population, 7.3 billion in 2015, is expected to grow to 9.7 billion by 2050.[10] By comparison, the current US population, 318.7 million, is expected to grow to 416.8 million by 2060, a projected increase of 98.1 million people.[11] In addition to growing in number, the population is also aging. In 2012, an estimated 43.1 million Americans were 65 and older. By 2050, this number is expected to almost double to 83.7 million, which will make up about 21% of the nation's population.[12] This is largely due to the significant rise in life expectancy. According to available data, people are living much longer—the average life expectancy from birth in the US is 78.8 years compared to 68.2 years in 1950.[13] Similarly, life expectancy for American men reaching the age of 65 is 18 years and for women, 20.5 years.[14]

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[10] United Nations, Department of Economic and Social Affairs, Population Division. World Population Prospects: The 2015 Revision, Key Findings and AdvanceTables. *Working Paper* No. ESA/P/WP.241. (2015).

[11] Sandra L.Colby and Jennifer M. Ortman. "Projections of the Size and Composition ofthe U.S. Population: 2014 to 2060" (Washington, DC: US Census Bureau. 25-1143, 2014)

[12]Jennifer M. Ortman, Victoria A. Velkoff, and Howard Hogan. "An aging nation: the older population in the United States." (Washington, DC: US Census Bureau, 2014), 25-1140.

[13]Elizabeth Arias. "Changes in Life Expectancy by Race and Hispanic Origin in the United States, 2013-2014." *NCHS data brief* 244, (2016): 1-8.

[14] Ibid.

3.2 Population of Hawai‘i

The changes to population growth and age occurring across the world are also happening in Hawai‘i. The state's population, currently 1.4 million, is expected to grow to 1.8 million by 2040.[15] Today, Honolulu's population, Hawai‘i's densest, is home to 67% of the state's total population, and is projected to hold 61% by 2040.[16] Just the urban Honolulu CDP area has about 352,769 people as of 2015; 25% of the total population of Hawaii.[17] This is approximately 5,829 people per square mile. (Fig. 1&2) In addition, a large portion of Hawai‘i's population is aging. Today, 14% of the population is 65 and older; by 2040, this is expected to grow to 23.6%. (Figure 3)

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[15] "Population and Economic Projections for the State of Hawaii to 2040." *Research and Economic Analysis Division Department of Business, Economic Development and Tourism*. (HI ,DBEDT 2040 Series., 2012).

[16] Ibid.

[17] "Annual Estimates of the Resident Population for Incorporated Places of 50,000 or More, Ranked by July 1, 2015 Population: April 1, 2010 to July 1, 2015 - United States -- Places of 50,000 Population more information 2015 Population Estimates," U.S. Census Bureau, accessed January 26, 2017, https://factfinder.census.gov/faces/tableservices

Figure 1: Population Density per Square Mile Oahu

Figure 2: Population Density per Square Mile, the rest of State
Source: Office of Planning (OP), U.S. Census Bureau, 2010. READ, DBEDT, 2011.

Figure 3: Aging Population in Hawai'i

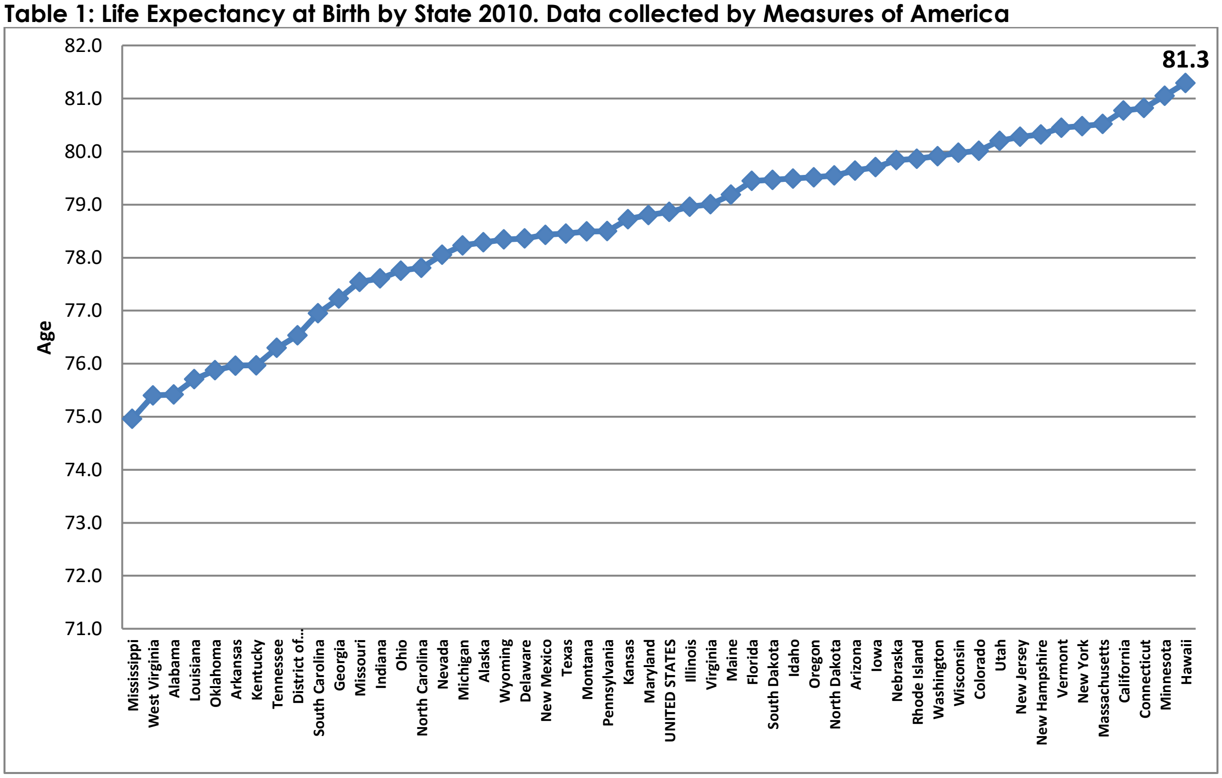
3.3 Life Expectancy in Hawai'i

As mentioned earlier, the primary reason for the aging of the population is the increase in life expectancy. Hawai'i leads the nation in life expectancy. According to *Measures of America*, in 2010 in Hawai'i, the average life expectancy at birth was 81.3 years (Table 1: Life Expectancy at Birth by State 2010. Data collected by Measures of America).[18] This data was obtained from a 2014 mortality rate report by the Department of Health and

[18]Kristen Lewis., and S. Burd-Sharps. "American Human Development Report: The Measure of America: 2013–2014." *Social Science Research Council*: Brooklyn, NY. (2015).

Services showing that Hawai'i has the lowest mortality rate after adjustment for age in comparison to the other states.[19]

Table 1: Life Expectancy at Birth by State 2010. Data collected by Measures of America



The continual rise in life expectancy over the past century reflects society's progress in the fields of healthcare and technology, influenced by a greater public health awareness and education; better diets and superior sources of nutrition; and widespread access to vaccines, medicines, and cutting-edge medical procedures. Human life has never been healthier.

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[19] Kenneth D. Kochanek et al. "Deaths: Final Data for 2014." *Hyattsville, MD: Dept. of Health and Human Services, Centers for Disease Control and Prevention, National Center for Health Statistics*, (2016).

However, despite these advances in healthcare services, technology, and treatments, issues still exist within the system. Many people are at risk from health threats directly related to the built environment. As population density increases, so too will urban development; metropolitan areas will expand and become more dynamic in use and infrastructure, exacerbating urban sprawl.[20] Changes in climate conditions, in part influenced by urban development, intensify the impact of physical spaces on human health.

To further investigate the impacts of physical environment on health, this research assesses the current living conditions of the older adult population living in the expanding and densifying urban fabric of Honolulu. This information will help answer the question, how can we design a living environment for older adults that promotes quality of life and adapts to society and climate changes?

4. Being Healthy

Various factors determine the overall health and well-being of a person and community. According to the World Health Organization (WHO), these depend heavily on the person's social status and living environment, and include where a person lives, the condition of his or her living environment, and his or her relationship with friends and family.[21] Access to

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[20] Howard Frumkin. "Urban sprawl and public health." *Public health reports* 117, no. 3 (2002): 201.

[21] Ibid.

quality healthcare falls lower on the list.[22] This information indicates that humans actually have somewhat less control of their health condition than popularly assumed.

4.1 Social Determinants

A person's social status, including income, has a large influence on his or her well-being.[23] This comes as no surprise; a person who has less money often has limited time and resources available to dedicate to his or her health, including a good education, a clean and comfortable living environment, and medication and health services. Poverty also carries with it psychological impacts that can affect a person's well-being.[24]

Relationships with friends and family also have a significant impact on psychological health. Time spent with loved ones provides people with emotional and practical support and allows them to feel cared for, loved, and valued, all positive contributions to human health.[25]

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[22] Ibid.
[23] Ibid.
[24] Richard G. Wilkinson, and Michael Gideon Marmot. "Social determinants of health: the solid facts." *World Health Organization*, (2003).
[25] Wilkinson. "Social determinants of health."

4.2 Built Environment

A person's quality of life is significantly affected by the built environment, including home, neighborhood buildings, streets, public spaces, as well as the general infrastructure—in other words, the places in which a person lives, works, and plays. Our relationship with the built environment is symbiotic. The physical condition of a person's home in particular affects his or her health, which is why human health has always been a major consideration in the design and construction of buildings. Architectural theorist Marc-Antoine Laugier, in *The Essay on Architecture,* writes that architecture's simple purpose is to shelter human beings from the elements of nature and therefore should be constructed with basic components like columns and a roof.

Judith Leavitt, in her book *The Healthiest City: Milwakee and the Politics of Health Reform*, writes that "the modern environment" is responsible for many of the population's health concerns. She credits the "unsanitary and overcrowded housing that had inadequate lighting and ventilation, as well as the unpaved streets that were littered with horse manure. This includes the poor condition or lack of water supply and improper waste system."[26] These environmental conditions resulted in epidemics of cholera, typhoid, yellow

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[26] Judith Walzer Leavitt*, "The Healthiest City: Milwaukee and the Politics of Health Reform"* (Princeton, NJ: Princeton University Press, 1982).

fever, and diphtheria.[27] Over time, however, urban spaces have evolved, the built environment has developed and improved, and public health has gained resilience through constant research and action.

Today, although tremendous progress has been made, the built environment, in many places and cases, still negatively affects people. Therefore, research continues to be conducted on the impact of built spaces. Architects, planners, and engineers use this research to find design solutions to these problems. In the book *Making Healthy Places: Designing and Building for Health, Well-being, and Sustainability,* Andrew Dannenberg, Howard Frumkin, and Richard Jackson investigate health issues related to various aspects of the environment, including transportation, housing, workplaces, healthcare settings, schools, nature, and disasters. For the purpose of this research, I will focus primarily on the health impacts of housing.

5. Health and the Indoor Environment

According to The National Human Activity Pattern Survey, "a two-year probability-based telephone survey (*n* = 9,386) of exposure-related human activities in the United States," respondents whom were random individuals with house phones across the U.S., spent 86.9% of their time indoors, 68.7% of whom lived in a residential environment, and 14.4% were aged 64 and

[27] Ibid.

older.[28] It is thus important to understand the impacts of indoor residential spaces on human health through various characteristics of the indoor environment, just as Cornell professor, Gary Evans conducted in his medical study; *The Built Environment and Mental Health*. In this research, Evans investigates characteristics of residential indoor environments, including housing typology, noise, indoor air quality, light, and thermal comfort. [29]

5.1 Impacts of Various Characteristics of Housing

Housing Typology

Home is commonly defined as a place where one feels comfortable and protected, which is generally true. Certain elements of a residence directly impact a person's well-being. One such element is the typology of the structure. In the case of high-rise residences for low income families, this impact is often negative due to lack of amenities and common spaces that promote social inclusiveness.[30] Several studies conducted on this topic determined that the demographic most affected by this is mothers with

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[28] Neil E. Klepeis, et. al. "The National Human Activity Pattern Survey (NHAPS): a resource for assessing exposure to environmental pollutants." *Journal of exposure analysis and environmental epidemiology* 11, no. 3 (2001): 231-252.

[29] Gary W. Evans. "The built environment and mental health." *Journal of Urban Health* 80, no. 4. (2003): 536-555.

[30] Evans. "The built environment and mental health."

children.[31,32] These women had more emotional disorders and their children became more socially isolated than peers who lived on the ground level.[33,34]

Older adults, especially those in the low-income bracket, are also affected by the high-rise typology. They often lack social support in high-rise buildings, experiencing social isolation, which negatively affects psychological health and can lead to further health complications.[35]

Noise

Noise is another factor that influences psychological health. Aside from typical effects such as sleep disturbance and stress, noise can also affect human performance. One study investigating children living near airports found that the constant noise of jet engines affected reading levels and the ability to complete complex tasks.[36]

Indoor Air Quality

The built environment is responsible for much of the air pollution that impacts human health, especially indoors. Air pollutants common to the outdoor environment from buildings, industry, and automobiles still have a substantial impact on indoor spaces. Major outdoor pollutants that affect

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[31] Brian T. Williams. "Health effects of living in high-rise flats." *International Journal of Environmental Health*, (1991).

[32] D. M. Fanning. "Families in flats." *British Medical Journal* 4, no. 5576 (1967): 382.

[33] Williams. "Health effects of living in high-rise flats."

[34] Fanning. "Families in flats."

[35] Robert Gifford. "The consequences of living in high-rise buildings." *Architectural science review* 50, no. 1 (2007): 2-17.

[36] Evans. "The built environment and mental health."

indoor air quality include benzene, carbon monoxide (CO), lead (Pb), nitrogen oxide (NOx), particulates (PM_{10}), sulphur dioxide (SO_2), volatile organic compounds (VOCs), and ozone (O_3).[37]

In addition to outdoor air pollution, the indoor environment emits its own pollutants called indoor volatile organic compounds (VOCs), which come from a combination of commercial products, interior finishes, furnishing, clothing, building materials, appliances, and water.[38] These pollutants have a greater impact on physical and physiological health than outdoor pollution. A common direct physical impact is called "sick building syndrome," and involves symptoms such as headaches, nausea, congestion, fatigue, fever, muscle pain, brain issues, and irritation of the eyes, throat, and skin.[39] Sick building syndrome may sometimes lead to larger health problems and rarely death.

Indoor air pollutants are a significant health hazard, and the older adult population, across multiple studies, is the most heavily affected, specifically in the area of respiratory health.[40,41,42] This is supported by data

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[37] Andy P. Jones. "Indoor air quality and health." *Atmospheric environment* 33, no. 28 1999: 4535-4564.

[38] Ibid.

[39] Ibid.

[40] Every Breath We Take: Improving Air Quality in Europe. *European Environment Agency Signals*. (Luxembourg: Publications Office of the European Union, 2013).

[41] Pope III, C. Arden, and Douglas W. Dockery. "Health effects of fine particulate air pollution: lines that connect." *Journal of the air & waste management association* 56, no. 6 (2006): 709-742.

[42] Bert Brunekreef, and Stephen T. Holgate. "Air pollution and health." *The lancet* 360, no. 9341 (2002): 1233-1242.

detailed in the Center for Disease Control (CDC) article "Trends in causes of death among older persons in the United States," which places respiratory deaths such as heart disease, certain types of cancer, pneumonia, and lower respiratory diseases, at the top of the list.[43] The problems that lead up to such deaths can all be significantly affected by the quality of indoor air.

In Hawaiʻi, the leading causes of death for adults 65 years and older also include respiratory-related deaths such as various forms of cancer, influenza and pneumonia, and chronic lower respiratory diseases.[44]

Light

Light level is another characteristic that has a significant impact on human health, especially physiological health. The most important form of light essential to human health is daylight. Multiple studies investigate the importance of daylight on neurological well-being. The most common impact of light deficiency is seasonal affective disorder (SAD), or depression from lack of daylight.[45] Generally, those who received less daylight experienced more performance issues such as fatigue, sadness, and

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43 Yelena Gorina, et al. "Trends in causes of death among older persons in the United States." *Aging trends* (Hyattsville, Md.) 6 (2005): 1.

44 "Leading Causes of Death in Hawaii by Age, 2000-2014." Report. *Hawaii Health Data Warehouse, Hawaii State Department of Health. Office of Health Status Monitoring; United States Census*. (2016)

45 Norman E. Rosenthal, et al. "Seasonal affective disorder: a description of the syndrome and preliminary findings with light therapy." *Archives of general psychiatry* 41, no. 1 (1984): 72-80.

depression.[46] This is the case for a study done in a hospital where patients in rooms that were exposed to daylight were leaving the hospital 2.6 days earlier than those who stayed with the less daylight rooms.[47] Similarly, a study in Sweden found that children in classrooms without windows had weaker performance than peers in classrooms with windows. This was the consequence of interrupted circadian rhythm from the lack of daylight.[48]

Thermal Comfort

Another environmental characteristic that affects human health is thermal comfort. The *ANSI/ASHRAE Standard 55-2013: Thermal Environmental Conditions for Human Occupancy* defines thermal comfort as "the condition of mind that expresses satisfaction with the thermal environment and is assessed by subjective evaluation." Thermal comfort is influenced by various elements that respond fundamentally to the environment such as direct radiation, humidity, convection (wind), radiant temperature, and air temperature. It is also influenced by the cultural aspect, or the activities and programs that impact the movement and clothing of the occupants.

The ASHRAE-55 identifies six factors used to measure indoor thermal comfort: metabolic rate, clothing, air temperature, radiant temperature,

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[46] Gary W. Evans "The Built Environment and Mental Health." *Journal of Urban Health* 80, no. 4, 2003. 536-555.

[47] Kathleen Beauchemin and Hays., 1996. Sunny hospital rooms expedite recovery from severe and refractory depressions. *Journal of affective disorders*, 40(1), pp.49-51.

[48] Rikard Küller and Carin Lindsten. "Health and behavior of children in classrooms with and without windows." *Journal of Environmental Psychology* 12, no. 4 (1992): 305-317.

convection, and humidity level.[49] These will serve as the tools to measure thermal comfort for the design portion of this research.

6. Global Warming

Pollution from the development and expansion of the urban environment, specifically greenhouse gas emission, is considered the leading cause of global warming. The main gas emitted is carbon dioxide (CO_2), which comprises 65% of total emissions.[50] Most greenhouse gas emissions (66%) come from the built environment itself, including buildings (6%), transportation (14%), industry (21%), and energy production (25%).[51] Figure xx shows CO_2 emission by country; the level of urban development is clearly a significant factor in emissions.

One significant consequence of global warming is an overall rise in global temperature. According the National Centers for Environmental Information, May of 2016 was characterized by warmer than average temperatures and record warmth across the globe. In fact, the "combined

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[49] A. S. H. R. A. E. Standard, "Standard 55-2004—Thermal Environmental Conditions for Human Occupancy." *ASHRAE Inc., Atlanta*, GA (2004).

[50] Rajendra K. Pachauri et al. *Climate change 2014: synthesis Report. Contribution of working groups I, II and III to the fifth assessment report of the intergovernmental panel on climate change*. IPCC, 2014.

[51] Pachauri. *Climate change 2014*

average temperature over global land and ocean surfaces for May 2016 was the highest for May in the 137-year period of record."[52]

The impacts of rising global temperature resonate throughout the world, causing natural disasters and environments that are detrimental to human life, particularly to the more vulnerable older adult population. A statistic report shows that of the 10,649 weather-related deaths in the U.S. from 2006 to 2010, 31% were due to exposure of excess natural heat, heat stroke, and or sun stroke, and 66% were due to exposure to excessive cold or hypothermia. [53] Older adults had the highest rate of mortality in these categories.[54] When comparing these data to location of death, the urbanization level had an influence in the number of deaths. For heat-related deaths, rates were slightly higher in large metropolitan centers than in rural areas. Cold-related deaths on the other hand mostly occurred in rural areas.[55] The slightly higher rate of heat-related deaths in urban areas may be related to urban heat island effect.

A study on the heat wave that occurred in Chicago in 1995 concluded that heat combined with humidity in the urban areas may have been the main cause of the 581 deaths, 73% of which were of those 65 years

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[52] NOAA National Centers for Environmental Information, State of the Climate: Global Analysis for May 2016, published online June 2016, retrieved on December 6, 2016 from http://www.ncdc.noaa.gov/sotc/global/201605.

[53] Jeffrey Berko. "*Deaths attributed to heat, cold, and other weather events in the United States, 2006-2010.*" (Public Health, 2016).

[54] Berko. "*Deaths attributed to.*"

[55] Ibid.

and older.[56] In 1999, another heat wave occurred in Chicago where the highest rate of heat-related mortalities was again among people 65 years and older.[57] During a heatwave that occurred in 2003 in France, almost 83% of the total deaths were among people 75 years and older and took place mostly in urban settings, about 35% of which were in homes (Figure 4).[58]

Figure 4: Excess mortality distribution of sex, age, and setting. France 2003. Poumadere et al.

There are many potential reasons older adults are more vulnerable to these conditions. One may be related to the body's reduced ability to adapt and respond to extreme conditions as it ages.[59] Another may be related to socioeconomic status, which determines the living environment and a person's ability to respond to changing climate conditions.[60] This is important for my research because Hawai'i's climate is experiencing more and more

[56] Steven Whitman, et al. "Mortality in Chicago attributed to the July 1995 heat wave." American Journal of public health 87, no. 9 (1997): 1515-1518.
[57] Mary P. Naughton, et al. "Heat-related mortality during a 1999 heat wave in Chicago." *American journal of preventive medicine* 22, no. 4 (2002): 221-227.
[58] Marc Poumadere, et al. "The 2003 heat wave in France: dangerous climate change here and now." *Risk analysis* 25, no. 6 (2005): 1483-1494.
[59] Glen P. Kenny, et al. "Heat stress in older individuals and patients with common chronic diseases." *Canadian Medical Association Journal* 182, no. 10 (2010): 1053-1060.
[60] Naughton, et al. "Heat-related mortality during"

temperature swings, including heat waves like those in Chicago and France, and humidity levels are higher than average due to its location near the ocean. In addition, Hawaiʻi has a large number of low income families and individuals.

7. Current Housing Options for Seniors in Hawaiʻi

Older adults in Hawaiʻi have various housing options including continuing care retirement communities (CCRCs), nursing homes, residential care homes, and other care facilities. They may also remain in their own homes where family members or outside services can help care for them.

CCRCs are an ideal model for older adults. These housing environments offer an independent lifestyle within a community setting and provide a continuum of services and care over time.[61] A majority of those who live in these environments are alone, widowed, divorced, separated, or never married.[62] The other care models, like nursing homes and residential care homes, are often chosen for those who need more help with their activities of daily living (ADLs).

A major problem with all of these choices is that they are expensive. Although CCRCs offer an ideal living situation for many older adults, the

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[61] Jane E. Zarem. "Today's continuing care retirement community (CCRC)." *Retrieved January* 27 (2010): 2015.

[62] Ibid.

entrance fee alone in the U.S. can range between $100,000 and $1 million depending on location.[63,64] This does not include monthly rates, ranging from $3,000 to $5,000, which increases over time as the need for services and care increases.[65] In Hawai'i for example, the entrance fee for 15 Craigside Continued Care Retirement Home ranges between $176,000 to $429,000 depending on the amount of occupancy. In addition, a monthly service fee is required which costs between $3,280 to $6,133.[66] Another CCRC in Hawaii is the Kahala Nui which has an entrance fee ranging from $546,410 to over $1,176,630 depending on the unit size and the amount of bedrooms.[67] The monthly service fee starts at $3,243 to $ $8,194, the cost goes up as the amount of bedroom, unit size and the amount of occupancy also increases.[68]

According to a report put out by the Joint Center for Housing Studies of Harvard University, the typical homeowner in the U.S. 65 years and older can afford nursing home costs for 42 months and non-housing-related

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[63] Jane Zarem. "Today's continuing care retirement community (CCRC)." *CCRC Task Force, American Seniors Housing Association* (2010): 9.

[64] "Caregiving Resource Center: Continuing Care Retirement Communities." *AARP*. Accessed December 14, 2016. http://www.aarp.org/relationships/caregiving-resource-center/info-09-2010/ho_continuing_care_retirement_communities.html.

[65] Ibid.

[66] "Costs | 15 Craigside," Arcadia Family of Companies, , accessed January 24, 2017, http://arcadia.org/companies/15-craigside/costs/.

[67] "Kāhala Nui: Residences: Island-Style Living: Island-Style Living." Kāhala Nui: Residences: Island-Style Living: Island-Style Living. Accessed January 24, 2017. http://www.kahalanui.com/indexbee2.html?page=residences§ion=floor_plan.

[68] Ibid.

expenses for 15 months.[69] On the other hand, the median older renter is not able to afford care service for even just one month. In fact, the report estimates that only 18% of renters can pay for nursing home care for more than one year.[70]

Race and ethnicity have a significant influence on homeownership. In the U.S., "among adults age 50 and over, 82 percent of whites own home, compared with just 58 percent of blacks, 62 percent of Hispanics, and 70 percent of Asians."[71] As the minority populations continue to grow, so will the population of older adults unable to afford proper housing and care.

Hawai'i has the reputation of being an expensive state to live in. For Hawai'i's older adults, this is especially true. According to the Genworth "Cost of Care Survey," the average 2016 cost in Hawai'i for a private room in a nursing home is over $141,000 annually and $113,000 in Honolulu. For single occupancy in an assisted living facility, the annual average cost is $48,000 and $51,000 in Honolulu. Home health aid service is $56,000 for the state and $58,000 for Honolulu.[72] Health ailments such as dementia and Alzheimer's disease further increase annual costs. In the average assisted living facility in

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[69] Kermit Baker, et al. "Housing America's older adults: meeting the needs of an aging population." *Cambridge: Joint Center for Housing Studies of Harvard University* (2014).
[70] Ibid.
[71] Ibid.
[72] "Genworth 2015 Cost of Care Survey Hawaii: State Specific Data" *Cost of Care Survey*, 118928HI (2015).

Hawai‘i, for instance, services and fees for Alzheimer’s disease care add nearly $12,000 to the annual cost.[73]

8. Hawai‘i’s Affordable Housing Crisis

Hawai‘i’s housing market is exceedingly expensive, and even rental properties are unaffordable to many working class families. Although the U.S. experienced a recent economic decline, the cost of rent continued to climb and the number of luxury units increased. Between 2005 and 2012, the average rent in Hawai‘i increased by 45% while the average wage only increased by 21%. Hawai‘i has the highest housing wage in the U.S. and, in fact, a fulltime worker would have to make at least $31.54 per hour to afford a two-bedroom market rental.[74]

To meet the demand for low-income households, Hawai‘i would have had to create 19,000 units by 2016 and this did not occur. Hawai‘i has the highest rate of homelessness in the nation, which is largely due to the lack of affordable housing. A major way to prevent homelessness is to provide more affordable housing.

9. Multigenerational Housing

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[73] “Market Survey of Longterm Care Costs.” *The 2012 MetLife.*

[74] “Hawai‘i’s Affordable Housing Crisis.” *Hawai‘i Appleseed Center for Law and Economic Justice Report: The High Cost of our Affordable Housing*, (2014).

Family Structures

Over time, because of shifting economic, political, and social conditions, the structure of the typical American household has undergone many changes. Our perceptions of a typical family are inspired by our experiences within the larger society. As a heterogeneous country, family structures vary tremendously based on race, ethnicity, education, age, and income of the adult family members.[75] The multigenerational household became one of the more favorable family structure overtime because of its overall benefits.

Before World War II, a large part of American society was agrarian and a typical family consisted of a husband and wife with children and an extended family. A majority of the those who could marry did and most stayed married until the death of the spouse; divorce was uncommon. This family structure was dominant and greatly influenced the cultural and social roles of family members.[76] Marriage was limited to heterosexual couples and men and women had distinct functions. Women were more likely to support the family at home, managing household responsibilities and taking care of the children and elderly. Men were the providers; their duty was to provide their wives with the financial necessities for a comfortable life and in return

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[75] James R. Wetzel "American families: 75 years of change." *Monthly Lab. Rev.* 113 (1990): 4.

[76] Courtney G. Joslin, *The Evolution of the American Family*, Vol. 36 No. 3 ed. (Chicago, IL: American Bar Association, 2009).

they had the right to their wives' services. In general, at least one child would stay with the parents into adulthood and would often take charge, providing continuous labor and support for the older members, bringing in a spouse, and thus advancing the household.[77] At the time, this structure made sense; because the society was largely agrarian, families needed to support each other in order sustain farms from generation to generation.

During WWII, the lives of the American people started to change. Society shifted from primarily agrarian to primarily urban due to the dramatic population growth and considerable numbers of immigrants arriving in the cities. As society adapted to technological advancements, changing economic conditions, and new social and cultural trends, so did the family structure; living arrangements became more diverse for everyone.

The role of wives changed dramatically. Many women joined the workforce to take the place of the men who were away fighting. This shortage of labor made it possible for women to attain jobs in many new industries. Women began to work full time while still attending to the needs of the children and the home. At the same time, many families who used to live on farms moved to the cities to find jobs. A combination of economic instability and shortage of housing and child-care facilities made life for these wartime families and working mothers challenging. As a result, divorce

[77] Steven Ruggles. "The transformation of American family structure." *The American Historical Review* 99, no. 1 (1994): 103-128.

became more common and marriages were postponed because couples could not afford to start families.[78]

After WWII, the U.S. experienced an economic boom and major social and cultural changes. There was a rise in marriage rates among younger couples and a sharp growth in birthrate.[79] The nuclear family—a working father, a stay-at-home mother, and the children—became popular and was considered the typical family, especially for middle income white families who were encouraged to move into the suburbs where widespread housing development was taking place. The suburban house, a single-family buliding with privatized bedrooms for the parents and children, a garage, and front and back lawns, was designed as the ideal American home. This period marked the birth of "suburban sprawl."

In the 1960s, the cultural climate shifted, influenced by events such as the civil rights movement, the Vietnam war, feminism, and other antiauthoritarian movements.[80] Divorce rates again began to rise and birthrates decreased. Cohabitation along with single-parent, female-led, same-sex, and extended family or multigenerational households became more common and influenced the idea of what was considered a typical

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[78] Sar A. Levitan and Richard Belous, "Working wives and mothers: what happens to family life?." *Monthly Labor Review* 104, no. 9 (1981): 26-30.

[79] James R. Wetzel. "American families: 75 years of change." *Monthly Lab. Rev*. 113 (1990): 4.

[80] Bahira Sherif-Trask. *Globalization and Families: Accelerated Systemic Social Change* (New York: Springer, 2010).

family. This dynamic variety of family structures is still dominant in the present day.

Today, the American family continues to change. Parents are raising their children in diverse and constantly evolving family structures. The multigenerational household remains one of the standards, and for the purposes of this research, we will look more closely at this form.

Multigenerational Families

During the nineteenth and early twentieth centuries, the multigenerational household was a necessity. Nuclear households expanded to meet the needs of family members, especially during housing shortages or when older adults, mostly the widowed, could no longer care for themselves independently.[81]

In the early twentieth century, the multigenerational family was still common; fertility rates had declined, life expectancy was higher, and family sizes were becoming smaller.[82] Often the multigenerational household consisted of a father, a mother, children, and an extended family member such as a grandparent. It was normal for the aging population to remain with their families until death. At this time, about 60% of elderly whites lived with their children, but by 1940, only about 40% did.

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[81] Tamara K. Hareven "Aging and generational relations: a historical and life course Perspective". *Annual Review of* Sociology 20, (1994). 442.

[82] Steven Ruggles. "The transformation of American family structure." *The American Historical Review* 99, no. 1 (1994): 103-128.

After WWII, the multigenerational family structure faded. During this period, the number of older adults living with their children dramatically decreased, the nuclear family became more prevalent, immigration rates declined, and there was a dramatic increase in the health and economic well-being of adults 65 years and older. By 1980 only about 15% of elderly whites still lived with their children.[83]

After 1980, however, multigenerational households started popping up again within all major demographics. Finding jobs and starting careers became more difficult for young people. [84] As a result, they began to marry later than before. In 1970, the average man married at 23 and the average women at 21. Today, the average man marries at 27 and the average woman at 26. Thus, largely for financial reasons, many people still live at home in their early 20s. More recent economic changes, such as the 2007 recession, also impacted the way people lived; Pew Research found that from 2007 to 2008, an additional 2.6 million people began living in multigenerational households.

Another cause for the increase in multigenerational families was the large influx of mostly Latin American and Asian immigrants that occurred in

[83] Steven Ruggles,. "Multigenerational families in nineteenth-century America." *Continuity and Change* 18, no. 1 (2003): 139-165.

[84] Greg Kaplan, "Boomerang Kids: Labor Market Dynamics and Moving Back Home." *Federal Reserve Bank of Minneapolis*, Working Paper 675, (2009).

the 1970s. The multigenerational household was already the standard family structure for many of these immigrants.[85]

Older Adults in Multigenerational Households

As the twentieth century progressed, older adults became healthier and wealthier, and new social welfare programs, like Social Security and Medicare, were established.[86] This allowed more older adults to live independently or in senior care facilities. By the 1980s, the number of older adults living in multigenerational households was at its lowest point in record, 17%. After 1990, however, this number began to rise again slightly. One possible reason for this shift is that the baby boom generation, a generation marked by families with multiple children, began to reach later middle age; this provided a greater number of possible family members for aging parents to move in with as they needed. Another possible reason is the 1997 changes in Medicare that gave financial incentive to older adults willing to move in with their grown children.

Older Adults Living Alone

Throughout the past century, the living arrangements of the older adult population have undergone more changes than those of any other age group. For example, from 1900 to 1990, the percentage of older adults living

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[85] Paul Taylor, et al. "The return of the multi-generational family household." *Pew Research Center* (2010).

[86] Taylor. "The return of."

in multigenerational households decreased from 57.4% to 16.8% but then began to rise again reaching 19.6% by 2008. Another example is the number of older adults who live alone; from 1900 to 1990, this percentage increased from 5.9% to 28.8%, and again decreased slightly to 27.4% by 2008. It is important to note variations in this statistic based on age. Since 1980, the most common age range of those living alone is 85 and over, and this percentage is continuing to increase. It is those 65 to 84 years of age whose pattern has shown a decrease from 28% in 1990 to 25.6% in 2008.[87]

There are many reasons for the significant increase in population of older adults living alone over the past century (until the trend shift at around 1990). One reason is people are living longer and healthier lives than before; a person born in 1900 was expected to live into his or her mid-40s, whereas a person born in 2006 is expected to live into his or her mid-70s, a trend expected to continue upward. Life expectancy for those 65 and older and 85 and older is now also increasing. In 2014, those who turned 65 were expected to live for another 19.3 years and those who turned 85 were expected to live 6 to 7 more years.[88]

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[87] Ibid.

[88] "Older Americans 2016: Key Indicators of Well-Being." *Federal Interagency Forum on Aging-Related Statistics*. Washington DC: Government Printing Office, 2016.

Figure 5: Population living alone and dependency level

The higher rates of life expectancy support the statistics of both the number of older adults living alone as well as those living in multigenerational households. Because adults are living healthier, longer lives, those ages 65 to 84 stay longer with their spouses and a growing number (up 1.8% between 1990 and 2008) are also now living with an adult child, an influence of post-college economic challenges.[89] Adults 85 and older are more likely to live with their children because they are more likely to be widowed; in 2008, 19.4% of adults 85 and older lived with their children, 2.7% more than those 65 to 84.[90] Furthermore, the number of adults living in nursing homes or other senior housing facilities is decreasing slightly. From 1970 to 2008, the percentage of adults 65 and older who lived in care facilities decreased

[89] Taylor. "The return of." 12.
[90] Ibid.

from 5.5% to 4.9%.[91] In general, the overall amount of people aged 65 and older living alone is decreasing; 28.8% in 1990 to 27.4% in 2010.[92] A result of a common value of people, as displayed on survey conducted in 2005 by Pew Research of random individuals showing that majority of the public believe it is a "family responsibility" for the adult children to care for elderly parents, which entails taking them into their homes.[93]

Thus, the changes in health, demographics, and economics are together influencing a growth in the multigenerational family structure, especially among the older adult population. In the U.S. today, a total of 4.3 million families live in multigenerational households. Hawaiʻi has the highest percentage per total households at 11.1%, due at least in part to the large Asian, Polynesian and other populations that are more attracted to this type of household.[94]

Multigenerational Household in Hawaiʻi

Between 2007 and 2011, multigenerational households has been increasing in the more recent years, between 2007 and 2010 there has been a growth of about 1.9%, in other words, 1 in every 5 households include an

[91] Ibid, 13.
[92] Ibid, 9.
[93] Ibid, 9.
[94] Daphne A. Lofquist "Multigenerational Households: 2009–2011." *American Community Survey Briefs* (2012).

additional adult.[95] In comparison to the other states, Hawai'i has the highest percentage of multigenerational households per the total amount of families at 11.1%. This is large part because Hawai'i has population is approximately 58% of Asian ethnicity[96] including the Hawaiian and other Pacific Islanders which makes up about 23.3% of the total population of Hawai'i. [97] These ethnic backgrounds are likely to be living in multigenerational households and in addition to this, the families of Hawai'i is unique in a way that they are multiethnic with a diverse culture. This diversity enforces intergenerational living such as the concept of "ohana" which is a very family centric belief. *'Ohana* or *na 'ohana* translates to "many families," a symbol that means a family as a whole; where every member is part of giving life, nourishment and support for the well-being of blood relatives as well as extended family members.[98] The native Hawaiians along with other pacific island families believe that the ohana is the center of it all, and this idea has spread

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[95] Suzanne Macartney and Laryssa Mykyta. "Poverty and shared households by state: 2011." *Washington, DC: US Department of Commerce* (2012)

[96] Jessica S Barnes. *Asian population: 2000: Census 2000 brief.* (DIANE Publishing, 2010).

[97] Elizabeth M. Grieco. "The native Hawaiian and other Pacific Islander population: 2000." Vol. 8, no. 2. *US Department of Commerce, Economics and Statistics Administration*, *US Census Bureau*, (2001).

[98] Valli Kalei Kanuha, "Na Ohana Native Hawaiian Families," ed. Monica McGoldrick , Joe Giordano and Nydia Garcia-Preto, in *Ethnicity and Family Therapy* (Guilford Press, 2005).

throughout the diversified culture of Hawaiʻi which every family of various ethnicities now live by.[99]

Another explanation for Hawaiʻi's large number of multigenerational households is economic status. According to "America's Families and Living Arrangements: 2012," "multigenerational households were more likely to be in poverty," and Hawaiʻi is no exception. The state is known for its high cost of living, and, in fact, Hawaiʻi's cost of housing is the highest in the nation. Rent costs and housing demand continues to rise despite economic decline. As mentioned earlier, the average rent in Hawaiʻi increased by 45% between 2005 and 2012 while the average wage only increased by 21% making it challenging for families to afford a decent home.[100]

For many older adults in Hawaiʻi, despite the long term care support and other benefits of residential care facilities and senior housing options, the cost of these types of living arrangement is not affordable. For example, one year in a nursing home in Hawaiʻi costs an average of $132,860 compared to the national average of $83,585; one year in an assisted living facility costs an average $50,676 compared to the national average of $39,512; and the average hourly rate for home health aide is $22 compared to the national

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[99] Ryan Kananiokahome Poiekeala Kanaka'ole. "Indivisible Ohana: Extending Native Hawaiian Gathering Rights to Non-Hawaiian Family Members." *Asian-Pacific L. & Pol'y J.* 12. (2011). 145-330

[100] *"Hawaiʻi's Affordable Housing Crisis."* (Hawaiʻi Appleseed Center for Law and Economic Justice,2014).

average of $21.[101] Some federal and state programs such as Medicaid provide financial support to older adults for care services. Seventy percent of older adults living in nursing homes in Hawai'I, for example, are financially supported by Medicaid.[102] However, despite available financial support, the number of long-term care facilities in Hawai'i is very low. Nursing homes, for example, had only 43.4 beds per 1,000 persons age 75 and older in 2009..

Ohana Dwelling, or Accessory Dwelling Unit

In response to the high cost of living and lack and high cost of long term care facilities, families must reinvent household structures and find alternative care solutions for their elderly. Multigenerational households are often most cost-effective and beneficial. One particular multigenerational household solution for many families, especially for those who own homes, is to build an ohana dwelling, or an accessory dwelling unit (ADU). This is a separate living area on a single-family lot that can be attached or detached from the existing home or primary dwelling unit.[103] ADUs were originally zoned for family relatives only but in September 2015, the City and County of Honolulu, passed a law allowing ADUs to be rented. ADUs, especially those meant only for relatives, help to preserve the multigenerational structure, are

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[101] Janet O'Keeffe, and Joshua M. Wiener. "*An overview of long-term care in Hawaii.*" (Washington, DC: RTI International, 2010).

[102] Janet O'Keeffe, and Joshua M. Wiener

[103] "Accessory Dwelling Unit Homeowners' Handbook: A Guide for Homeowners on Oahu Interested in Building an Accessory Dwelling Unit" (Hawai'i Appleseed Center for Law and Economic Justice, 2016).

often more affordable than long-term care services for families with older adults, and help to prevent overcrowding of the primary unit.[104] Even so, challenges exist around the implementation of ADUs, specifically related to land zoning laws.

ADU Land Zoning

ADUs are permitted on any lot where zoning normally allows it. In figure xx, the green areas on the map represent properties zoned for ADUs while the brown circles depict the distribution of actual multigenerational households with ADUs on Oahu. The map clearly shows that there are not many overlaps between the permitted zones and the actual built ADUs.[105] Despite the lack of governmental support through zoning and permitting, many families persist and build ADUs on their properties.[106] This shows the strong preference for multigenerational households that exists in Hawaiʻi, even if perhaps this is only because it is the most economical option.

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[104] "Housing Policy Accessory Dwelling Units: Expanding Affordable Housing Options in Hawaiʻi." (Hawaiʻi Appleseed Center for Law and Economic Justice).

[105] Quester Lau, "Black Boxes and Gray Spaces." 7.

[106] Ibid.

Figure 6: Comparison of Multigenerational Households to the Ohana Zone. Source: U.S. Census

Caregiver Stress

A downside to sharing multigenerational households with older adults is caregiver stress. According to numerous elderly care and housing studies, many older adults depend on their adult relatives for care and financial support. By the age of 65, 45% of adults will rely on adult relatives for long-term care cost.[107] Family care givers often experience various long-term hardships such as reduced time for work, less promotions, reduced retirement

[107] Ritabelle Fernandes, and Hortense M Gandy. *Services &Housing Options for Seniors on Oahu*. 2013. 3. Web.(2011).

and social security income, limited opportunity to pursue personal goals, depression, and health and mental stress.[108]

Long-term caregiving within a family is sometimes detrimental to both the caregiver and the elder. Family stress related to caregiving is often the reason families that can afford it place older adults into care facilities.[109]

Isolation in Long-Term Care Facilities

Families choose to place their elderly members in long-term care facilities because of the benefits in health care assistance and the caregiving support. However, despite how helpful long term care facilities may seem, they are still largely considered an unattractive living option primarily because older adults have to be displaced from their current homes and lives to live in an age-segregated environment which doesn't always have a good outcome[110] and can be harmful and unhealthy. When older adults, especially those who are unmarried or widowed, have no children, or live far from their children, are placed in senior care facilities, the risk of becoming socially isolated rises dramatically. In most cases, older adults who are isolated are less happy, less healthy, and often more

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108 David Nixon. "Tax Incentives for Family Caregiving: A Cost-BenefitAnalysis." *College of Social Sciences, Public Policy Center;University of Hawaii at Manoa*,(2008).

109 "Caring for Our Kupuna: Building an Aging in Place Movement in Hawaii." Report. *Hawaii Community Foundation & Nonprofit Finance Fund*, (2013).

110 Benyamin Schwarz and Ruth Brent. Tofle, Aging, Autonomy, and *Architecture: Advances in Assisted Living* (Baltimore, Md: Johns Hopkins University Press, 1999).12.

depressed than those who are not alone.[111] In addition to emotional distress, older adults who are alone are less active and have less opportunities to enjoy the good aspects of life. For example, a survey done on adults ages 65 and older, found that of those living alone reported having less time with their families than those living with a spouse or family.[112] Likewise, those alone reported spending less time doing hobbies, volunteering, or getting involved with community events than peers who did not live alone.[113] A study conducted from 2004 to 2005 found that adults 52 years and older had higher mortality rates related to social isolation and loneliness.[114]

Benefits and Challenges

Life in a multigenerational household offers many benefits. When multiple members and generations live together in a single household, there are more opportunities to both give and receive support and care, which promotes quality of life. For example, the care of a child can be shared by both parent and grandparent. This can create healthier relationships; the child receives love and wisdom from the grandparent, the parent receives general support and time, and the grandparent gains emotional benefits that reduce psychological strain and provide a continued sense of purpose.

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[111] Paul Taylor, et al. "The rzgeturn of the multi-generational family household." *Pew Research Center* (2010).
[112] Paul Taylor, et al. "The return of the Mult."
[113] Ibid.
[114] Andrew Steptoe, et al. "Social isolation, loneliness, and all-cause mortality in older men and women." *Proceedings of the National Academy of Sciences* 110, no. 15 (2013): 5797-5801.

In the long run when the child becomes an adult, he or she might one day care similarly for his or her grandparent.

Another significant benefit of living in a multigenerational household is that it reduces mistreatment of older adults.[115] The multigenerational household can reduce the opportunity for such abuses by According to the AARP article “Federal Response to Elder Abuse Fragmented,” about 14% of “older Americans [have] been victimized physically, emotionally or financially... Some $2.6 billion of their savings and investments were lost, mishandled, squandered” in reducing financial stress. In such a household, there are potentially multiple sources of income as well as a reduction of expenses related to child care when a grandparent takes care of the child, which may also improve flexibility related to work hours and experience.

Reflection

Although the multigenerational family structure may seem like the ideal type of household, it does not work for everyone. An important aspect of intergenerational living creating a peaceful environment despite the diversity of personalities involved. Each person has his or her unique characteristics and personality; sometimes families find it difficult to

[115] Jim Toedtman. "Federal Reponse to Elder Abuse Fragmented." *AARP Bulletin Print Edition*, April 1, 2011. Accessed November 23, 2016. http://www.aarp.org/politics-society/advocacy/info-04-2011/elder-abuse.html.

cooperate with each other or coexist.[116] These differences within families with an elder can result in separation, placement of the elder member in a care facility, and even physical or psychological mistreatment. Even so, the overall benefits of the multigenerational family structure outweigh the negatives in many cases, which is why it is a family structure still common today.

As the population grows, high-rise buildings are increasingly the dominant typology for new residences in urban centers, primarily for their capacity to house large densities of people with a minimal footprint. High-rise residential buildings are also more economical from a developer's perspective, which in turn makes them a more economical option for families than single-family homes. The high-rise residential building is especially important for a city like Honolulu with limited land space and may perhaps become the architecture of future urban living.

In response to population growth, high-rise structures are being built, and in response to the aging of the population along with increasing economic hardship, the multigenerational household is becoming the ideal family structure. This brings attention to the next part of my research, which combines multigenerational living with high-rise residential buildings. I believe this architectural concept will respond to both the residential needs of the

[116]Sharon Graham Niederhaus, and John L. Graham. *Together Again: A Creative Guide to Successful Multi-Generational Living.* (M. Evans, 2007). 278

Figure 6: Comparison of Multigenerational Households to the Ohana Zone. Source: U.S. Census

Caregiver Stress

A downside to sharing multigenerational households with older adults is caregiver stress. According to numerous elderly care and housing studies, many older adults depend on their adult relatives for care and financial support. By the age of 65, 45% of adults will rely on adult relatives for long-term care cost.[107] Family care givers often experience various long-term hardships such as reduced time for work, less promotions, reduced retirement

[107] Ritabelle Fernandes, and Hortense M Gandy. *Services &Housing Options for Seniors on Oahu*. 2013. 3. Web.(2011).

were conducted and conferences held on issues related to high-rise living, including social impacts, crime, mental health, physical health, and the impacts on families and children.[118] However, despite the disadvantages of the high-rise residence, it remains a typology central to the future of our cities. Today, architects are looking into ways to make high-rise buildings healthier and more sustainable. Environmental, social, and psychological factors are central for the design of high-rise residences that promote the well-being of the occupants.[119] Environmental factors that have significant impact on human health and well-being include wind, sunlight, daylighting, air quality, noise, and vegetation. For instance, the design and placement of a high-rise building affects the way wind and pollution travel through the urban fabric and in and around the building itself.[120] Furthermore, high-rise buildings absorb and reflect solar radiation, which causes a phenomenon called urban heat island effect that increases the overall temperature of the urban environment and directly impacts indoor thermal comfort for the building's occupants.[121]

Majority of the existing high-rise buildings in Honolulu were constructed in the late twentieth century between 1960 to 1980, with definite influence

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[118] Robert Gifford. "The consequences of living in high-rise buildings." *Architectural science review* 50, no. 1 (2007): 2-17.

[119] Gifford, . "The consequences of."

[120] H Hayati,., and M. H. Sayadi. "Impact of tall buildings in environmental pollution." *Environmental Skeptics and Critics* 1, no. 1 (2012): 8.

[121] Ibid.

from the modern movement in architecture particularly the international style.[122] Residential high-rises including hotels were generally constructed with their lanais' to allow the occupants to enjoy the tropical climate of Hawaii.[123] Most of the older residential and hotel high-rises relied on natural ventilation for cooling, primarily because of Hawaii's moderate climate but the invention of the air-condition altered the way architects designed buildings. Some of these older high-rises that were originally naturally ventilated may have been renovated to adapt to the use of air-conditioning. Air-condition was used commonly on commercial and office buildings, and it wasn't until the late 1960's that residential high-rises began to utilize this technology.[124] Like the Princess Leilani condominium apartment on 1561 Kanunu St. and the Wailana on 1860 Ala Moana Blvd., which were constructed with full air-conditioned apartments.[125] By 1969, six additional condominium high-rises were under construction with fully air conditioned units, and as air condition grew popularity, buildings became more enclosed and the use of naturally ventilation had lost its need.[126]

The new residential high-rise being designed today is no different, most of the newly constructed high-rises in Ward and Kaka'ako development are

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[122] "High-rise Buildings in Honolulu." EMPORIS.

[123] Fung Asossiates, inc . *Hawaii Modernism Context Study*. Report. Historic Hawaii Foundation, 2011. Accessed January 26, 2017. http://historichawaii.org/wp-content/uploads/2013/11/HawaiiModernismContextStudy_Nov2011.pdf. 4-28.

[124] Ibid, 4-52.

[125] Ibid.

[126] Ibid,.

all enclosed with curtain glass walls, to maximize the view for each unit and fully air conditioned to provide comfort. Having a thermally controlled room is definitely a way to provide a comfortable indoor environment; however the disadvantage to this is that it uses too much energy, therefore increasing the electricity bill. More importantly, reducing openings on buildings for air conditioning not only limits the amount of ventilation for fresh air, it also minimizes the amount of daylight that enters the indoor spaces. In addition, it also decreases the visibility of the exterior landscapes. These are consequences that promote unhealthy outcomes for the occupants. The high-rises being constructed today with full curtain glass walls enclosure may maximize the view of the landscapes and may also increase daylighting, but without passive climate control systems, there would be large amount of solar heat gains that would enter through the buildings, intensifying the use of air-conditioning. This is somewhat counterproductive, and the energy use increases tremendously. Furthermore, air conditioning affects the way occupants perceive comfort, in that for those who are exposed to naturally ventilated environments have a wider range of temperature and humidity level that they perceive comfortable than those who have been accustomed to air-conditioned spaces.[127]

Social factors are another important consideration in the design of high-rise architecture. High-rise buildings environments often lack a sense of

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[127] Furuhash, Field Guide, 11.

community and are not conducive to social inclusion between neighborhoods and dwelling units within the building itself.[128] This is a major issue, especially for older adults who are most vulnerable to social isolation.[129] Older adults living in high-rise buildings experience similar psychological issues, such as isolation or loneliness, to those living in senior care facilities. One study found that older adults living in high-rise buildings were likely to experience psychological health problems like stress, depression, schizophrenia, and phobias.[130] This is especially the case with older adults that are low income, less educated, unmarried, and have more medical issues and minimal social interaction.[131] People who live in high-rise buildings tend to have few close friends among residents in the same building, and despite having more encounters than those living in low-rise buildings, they have fewer close relationships with their neighbors.[132]

Older adults who experience social isolation have higher mortality rates, possibly due to the lack of available contacts in cases of medical emergencies.[133] Similarly, socially isolated older adults often experience loneliness, which can have negative effects on both physical and mental

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[128] Gifford, . "The consequences of."

[129] Ibid.

[130] Robert Gifford. "The consequences of living in high-rise buildings." *Architectural science review* 50, no. 1, (2007). 2-17.

[131] A. Churchman and Ginsberg, Y. "The image and experience of high rise housing in Israel." *Journal of Environmental Psychology*, 4, (1984). 27-41.

[132] R. C Williamson. "Socialization in the high-rise: A cross-national comparison." *Ekistics*, 45,(1978). 122-130.

[133] Ibid.

health and can raise the risk of illnesses such as dementia.[134] The lack of semiprivate spaces, scarcity of accidental meetings between residents, and inflexible spatial adaptability due to fixed spaces all affect the social impacts of high-rise buildings.[135]

Psychological factors are also a major consideration when designing high-rise buildings. The most affected demographic, as mentioned earlier, is mothers with children. According to numerous studies, safety concerns and the challenges of supervising from a distance significantly limit the amount of time children in high-rise residences spend outdoors.[136] In addition, children who live in high-rise residences display more psychological distress and experience more learning difficulties than children who live in low-rise residential units.[137]

11. Design Principle

In his book *The Meaning of the Built Environment*, architect and author Amos Rapoport writes, "It is the users' meaning that is important, not the architects' or critics'." This introduces an important question: for whom do we design architecture? As an architecture student, I perceive architecture as

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[134] Laura Fratiglioni et al. "An active and socially integrated lifestyle in late life might protect against dementia." *The Lancet Neurology* 3, no. 6 (2004): 343-353.

[135] Baqar A. Husaini, et al. "Social and psychological well-being of Black elderly living in high-rises for the elderly." *Journal of Gerontological Social Work* 16, no. 3-4 (1991): 57-78.

[136] Brian T. Williams, "Health effects of living in high-rise flats." *International Journal of Environmental Health Research* 1, no. 3 (1991): 123-131.

[137] Ibid.

fundamentally aesthetic in nature, a statement that can be said of many in the profession. At the same time, most design projects are largely dependent on the client and, in many cases, primarily influenced by financial factors. Consideration for human needs is never fully integrated into the design process. This can and does have negative consequences in the lives of a building's occupants.

I believe that architects have a responsibility in shaping the physical environment and should start by prioritizing human health. This is not a new concept; principles and guidelines for creating designs that prioritize people and health do exist (i.e., the Urban Land Institute Ten Principles for Designing Healthy Places, the Well Building Standard). Through this research, I promote this by creating a design criterion for high-rise buildings in Honolulu, Hawai'i that improves the living environment while meeting the specific needs of the older adult population.

It is clear from the overview of the current living conditions of the older adult population that physical environment has a major impact on health, particularly for the this demographic and even more so for those in high-density urban centers like Honolulu. Health is directly affected by factors such as housing type, outdoor environment, indoor air quality, and light and thermal properties, and climate change further intensifies these conditions. Psychological health is also greatly affected by one's environment. In

Hawai'i, unfortunately, many available housing options for older adults are socially limiting or isolating, which can have long-term negative impacts.

Thus, this research proposes a design criterion for high-rise residential buildings that promotes a healthy lifestyle and quality of life for older adult residents. This will serve as a prototype for a healthier alternative housing for older adults in Honolulu. The design criteria is made up of three design principles: adaptive, bioclimatic, and biophilic. To evaluate the design principles, each will be compared to characteristics common of Blue Zone communities, defined in later sections.

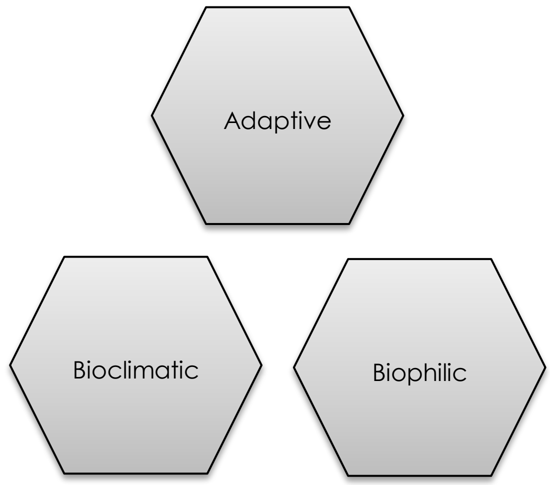

Figure 7: Design Principles

12. Adaptive Design

12.1 Multigenerational Household

In Honolulu today, multigenerational families have several residence options; they can own or rent a single- or multi-family house or a single- or multi-family building unit. The most ideal multigenerational household is a primary dwelling that includes an ADU because of its affordability and adaptability. For multigenerational families, adaptive dwellings are important; the environment can adapt as the family changes.

In order for a residential environment to be socially, economically, and environmentally viable, it must have a flexible design.[138] Adaptive or flexible

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[138] Tatjana Schneider, and Jeremy Till. "Flexible housing: opportunities and limits." *Architectural Research Quarterly* 9, no. 02, (2005): 157-166.

architecture is nothing new; it is a concept applied to many housing types and today is still an innovative solution for housing development.

Majority of families in Honolulu today, much like those in developed cities around the nation, perceive housing as a disposable commodity.[139] In other words, when a family's needs change, they often choose to relocate rather than make suitable changes to their current residence. This is largely a fault of the system in place; developers prefer static housing layouts, which keep the demand high.[140] It is therefore important to show developers that flexible and adaptive dwellings can be profitable by both adding value to property and giving people what they want.

The ADU is a type of adaptive architecture that is in high demand in Hawaiʻi, particularly in Honolulu. The Department of Permitting and Planning issued a total of 102 permits in Honolulu alone from 2005 to 2012; this does not including the 5,680 existing illegal ADUs.[141] In an assessment of families living in 3-bedroom, 2-bath homes in Honolulu, the most common issue reported was the lack of flexibility of space concerning the changing dynamics of daily needs, lifestyle, and culture.[142]

Affordability

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[139] Ibid,37.

[140] Schneider. "Flexible housing: opportunities and limits"

[141] Quester Lau. "Black Boxes and Gray Spaces: How Illegal Accessory Dwellings Find Regulatory Loopholes." *Master's thesis, University of Hawaii School of Architecture*, 2014.

[142] Ryan Shidaki, Multigenerational Living in the Urban High-Rise: Designing for Hawaii's Extended Family, Master's thesis, (University of Hawaii School of Architecture, 2009).

A major issue that Hawaii faces today is the lack of affordable housing. There is not an ultimate solution to solving this very complex and dynamic issue of housing crisis that is occurring around the world especially in Hawaii. However, adaptive design is a concept that would add to the innovation in housing design which further progresses the ideas to solving the housing crisis. As discussed by Schneider and Till, *obsolescence* is a major factor in the development of adaptive architecture.[143] Many of the buildings that are constructed to this day incur obsolete qualities, which in these case buildings that lose its value and become outdated from new standards or demands of the population, and the cost of retrofitting or a constructing a new building seems like more practical option.

Today obsolescence is large part of the human culture that we all have grown to accept. When the products we buy become outdated, break, or no longer fit our needs; they are often expected to be replaced.[144,145] The wide acceptance of this trend limits the advancement and research in the progress and improvement of the quality and the design of housing. Adaptable housing for this matter is a concept that opposes obsolescence which in turn, increases the lifespan and use of a residential building by allowing the architecture to adapt to changes overtime, In turn

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143 Schneider. *Flexible Housing*.35-36.

144 Ibid. 37.

145 Jia Beisi. "Flexible housing, compact city and environmental preservation: A critical look at Hong Kong's experience." *Open house international* 26, no. 1 (2001), 461.

reducing the cost of having to move to a new home or reconstruction.[146] Cost is also reduced by reducing the unit size and optimization of space for multiple functions.[147] Seemingly, this concept evokes qualities that promote an increase of value and a sense of ownership for the occupants, therefore reducing the need to move to a new home for residents, or constructing a new building for the developers. There are various studies and research that supports the advantages of adaptive design in housing including its affordable qualities; however affordable housing is obviously a complex and dynamic subject which requires immense research. Although adaptability in housing offers evident solutions to the issues of affordable housing, further investigations are required.

Design Flexibility

Adaptive design is understandably not a new concept in architecture, this idea has been researched and investigated in the past such as the Maison Domino (1914) by Le Corbusier, which demonstrated that a building consisting of the basic floor slabs and columns, opens infinite possibilities of potential floor plan.[148] This idea continues to be explored and progressed to this day. Flexible housing is generally defined as housing that gives the

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[146] Schneider. *Flexible Housing*.35-36.
[147] Avi Friedman. "Design for Flexibility and Affordability: learning from the post-war home." *Journal of architectural and planning research* (1997): 150-170.
[148] Jia Beisi. "Adaptable Housing or Adaptable People?." *Experience in Switzerland gives a new answer to the questions of housing adaptability, Arch. & Comport* 1 (1995): 139-162.

possibility for its environment to be adjusted to the changing needs of the occupants (e.g., when family members age or new members are introduced), and is intentionally broad and can relate to anything from dwelling type, internal flexibility, and technological applications, to overall flexibility of the building. [149,150] Adaptability is a similar concept, but has a more specific definition, that is, housing that is designed for multipurpose use, primarily though layout arrangement and organization to be able to adapt to demographic, social, or cultural changes in the household without having to physically adjust the environment.[151] Both flexibility and adaptability in dwellings allow for long-term use by providing an environment that allows change based on user needs rather than forcing the user to adjust to a fixed environment. It is also important that the users have the knowledge and for the adaptive strategies to be easily operable for the users in order to function properly.[152]

In this research, flexible and adaptable housing is defined and used similarly, which is based on the ability for the environment to adjust to change and occupant needs, particularly social and demographic reasons. The design strategy of this research is to create a multigenerational high-rise building that consists of dwelling units for various family sizes capable of

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[149] Schneider. *Flexible Housing*.4.
[150] Friedman. Design for Flexibility. 160.
[151] Ibid. 5.
[152] Beisi. Adaptable Housing, 155,161.

adapting to family growth and evolution. This residential high-rise could be interpreted as an intergenerational community in a building. To achieve a successful adaptive dwelling, a minimal amount of intervention must be required to make adjustments to the environment.

Soft and Hard Concept

In the book *Flexible Housing,* Tatjana Schneider and Jeremy Till introduce the concepts "soft" and "hard" for categorizing elements of flexible housing. Soft design elements have undecided uses or functions whereas hard design solutions have pre-determined uses or functions.[153]

Soft-use projects generally require user interaction with the environment in order to make the changes needed over time. According to Schneider and Till, this design technique is "relaxed and indeterminate."[154] The architect's role is minimal; the unit layout, if spacious enough, is mostly under the control of the occupants. The hard approach, on the other hand, gives more control to the architect, who defines the potential adjustments that can be made in a space over time. This is common in units with limited space.[155] In the following section, strategies for achieving flexibility are discussed.

Levels of Flexibility

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[153] Schneider. *Flexible Housing*, 7.
[154] Ibid.
[155] Ibid.

Different strategies that can be applied in a building design contain various levels of flexibility, from small to large scale and from simple to complex. Schneider and Till organized design solutions which consist of three levels of flexibility depending on the relation of each to a scale of modification.[156]

The figures in the following sections show some of the different strategies for achieving flexibility organized by level of modification. The strategies laid out represent some common and basic approaches to achieving adaptability.

12.2 Building Level

Fig. 4,5,6 From Tatjana Schneider and Jeremy Till, Flexible Housing (Oxford, UK: Architectural Press, 2007), 183-185.

[156] Ibid, 6.

Figure 8: Horizontal addition

Figure 9: Vertical addition

Figure 10: Slack spaces

Building Level Strategies

Flexibility in the "building level" is a large scale strategy for achieving adaptability. This usually refers to external changes like horizontal (Figure 8) or vertical (Figure 9) additions. These strategies sometimes require external space and a building structure that supports future expansions.[157] However, internal spaces such as unfinished or enclosed spaces may be the simplest form of expansion of the living spaces.[158] It is important to note that this strategy may reduce daylighting capabilities from the external build-outs that change the building façade. For vertical additions, if a building has pitched roofs, open roof rafters should be applied, but for flat roofs, structural stability to support future expansions should be built in.[159]

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[157] Tatjana Schneider and Jeremy Till, *Flexible Housing* (Oxford, UK: Architectural Press, 2007), 183.

[158] Friedman. *Design for Flexibility*, 161.

[159] Schneider. *Flexible Housing*, 184.

Common circulation spaces such as corridors or stairs can also provide flexibility, especially if external. This can help with buildings that have limited interior space. Common circulation spaces can have multiple uses, including eating, sitting, and gardening, which also improves the overall sociability of the building.[160] Slack spaces are usually common spaces like courtyards, corridors, stairwells, flat roofs, lanais, or service spaces.[161] These areas hold potential for future expansions or additions.

12.3 Unit Level

Fig. 8-16 from Tatjana Schneider and Jeremy Till, *Flexible Housing* (Oxford, UK: Architectural Press, 2007), 186-191.

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[160] Ibid, 185.
[161] Ibid*, 182*.

Figure 11: Neutral spaces

Figure 12: Circulations

Figure 13: Joining rooms or units

Figure 14: Joining and dividing units

Figure 15: Multiple entrances

Figure 16: Shared rooms

Unit Level Strategies

Adaptable unit level is similar to internal flexibility which is a medium scale strategy for achieving flexibility that allows modification of the housing unit to accommodate for various living patterns.[162] Adaptable unit levels strategies include, circulations, joining rooms, joining and dividing units, multiple entrances, and shared spaces.

Neutral rooms are unlabeled rooms with no specific function; this allows occupants to adjust the room to meet their needs and to be able to

[162] Ibid.

make modifications over time as needs change (Figure 11) In order to achieve this, room dimensions in a unit need to be fairly consistent, which means the dimensions of the standard living room would be reduced and those of the bedrooms, increased.[163] According to Schneider and Till, the minimum ideal dimensions for a neutral room are 12 feet by 13 feet but can be as small as 10.5 feet by 12.5 feet.

Circulation spaces inside units can also be designed to improve flexibility and, if large enough, can be used for other functions as well such as shelving, storage, or child play space (Figure 12).[164] Joining rooms is another strategy for promoting flexibility (Figure 13). With this approach, two units can be joined to create a larger space by removing light, moveable partitions.[165] This design strategy is generally cost-efficient.[166] An example of joining rooms common in Hawaiʻi is the ADU. Dividing units is a similar concept, only it achieves flexibility by reducing the unit size (Figure 14). In order for this to be achieved, various entry points (Figure 15) need to be incorporated into the layout to provide flexible circulation.[167]

Shared spaces are another common approach to design flexibility (Figure 16). This strategy is very simple; it is a room or space between two units with no specific function that can later be added to one of the units as

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[163] Ibid.
[164] Ibid, 187.
[165] Ibid.
[166] Ibid.
[167] Ibid,188.

an extra bedroom or work space.[168] Service cores are another building elements that can be designed to promote flexibility. Proper positioning is essential because they are often permanent.[169] So when designing the service core, the architect must consider the influence these elements have in the overall flexibility of the unit.

12.4 Room Level

Figure 17: Connection between rooms

Figure 18: Collapsible furniture

Figure 19: Operable walls

Room Level Strategies

[168] Ibid, 189.
[169] Ibid.

Room level pertains to small scale flexibility within individual rooms themselves. Flexible room are potentially adaptable to various needs, both immediate and long-term.[170] This can be done through connections between rooms, collapsible furniture, or operable walls. Connections between rooms can be accomplished using movable wall partitions or doors (Figure 17).[171] The use of movable partitions or furniture as dividers are often designed in the pre-occupancy stage for various users. Foldable furniture, usually beds and tables, is another room level strategy that is an easy, high-tech approach to the immediate transformation of rooms as needed.[172] In order for foldable furniture to work properly, the furniture itself has to be taken into consideration when designing room layouts.[173]

The movable or sliding wall is perhaps the most common strategy used when designing flexible rooms because of its simplicity, ease of use, and low-cost approach (Figure 19).[174] There are many types of moveable walls, including curtains, sliding walls, and folding partitions.[175]

12.5 Building Construction

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[170] Ibid, 182.
[171] Ibid, 190.
[172] Ibid.
[173] Ibid.
[174] Ibid, 191.
[175] Ibid.

Fig 17-22 from Tatjana Schneider and Jeremy Till, Flexible Housing (Oxford, UK: Architectural Press, 2007), 194-199.

Figure 20: Disassembly

Figure 21: Clear spans

Figure 22: Partitions

Figure 23: Horizontal services

Figure 24: Vertical services

Building Construction Principles

The strategies already discusses must be planned into the design of the units or the architectural layout,[176] but in order for them to work properly, the construction of the building itself must also be considered.[177] Construction principles consist of the structural systems, building layers, and the building's simplicity and constructability.[178] The structural systems of a building are likely to be fixed and permanent, therefore they have a significant influence on

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[176] Ibid, 182.
[177] Ibid, 192.
[178] Ibid.

the flexibility of the interior layout. In general, the more space that the structure provides on the floor to provide a more open layout, the larger opportunity there is in adapting to change.[179,180] Building layers refer to the various layers of building elements, each of which is essential and should be considered individually, particularly because of each one's different lifespan.[181] Also, it is important to keep the overall layout and construction of the building simple in order to promote easier adaptation of the spaces over time.[182] Finally, in order to achieve flexibility, designers must consider the assembly of the different layers (Figure 20), including building components that can be disassembled for transformation or replacement.[183]

In addition to the construction principles of flexibility, additional construction strategies that promote flexibility should be considered. These are clear spans, partitions, and horizontal and vertical service spaces. Clear spans are internal partitions that do not carry any loads and are light framed (Figure 21); they can therefore be moved around based on need.[184] Clear spans are achieved through open floor plans which offer the most flexibility in its function by giving the users an unfinished floor and giving them the control in defining the layout of the space according to their needs.[185] Partitions are

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[179] Ibid,192.
[180] Friedman. *Design for Flexibility*, 162.
[181] Schneider. *Flexible Housing*,193.
[182] Ibid, 194.
[183] Ibid, 193-194,
[184] Ibid, 195.
[185] Friedman. *Design for Flexibility*, 162.

a wall type that can be removed in order to change a space (Figure 22). Partitions must also therefore be non-loadbearing and lightly framed and should not include electrical or plumbing components.[186] Partitions are a commonly strategy because of their low cost and high potential for flexibility.[187]

As mentioned previously, proper location and flexible construction of the service systems is essential because these are usually the most permanent components of a building. Therefore, when designing for flexibility, it is important to understand the influence of the service systems on the adaptability of the units and the overall building over time. An approach to achieving this is the use of vertical or horizontal service systems. Vertical services are typically located within a building shaft or a riser and are often grouped into one area, like the building core (Figure 24).[188] Although permanent, it is important that these systems are accessible and allow for future replacement or additions. Horizontal service systems are usually placed within suspended ceilings or raised flooring (Figure 23).[189]

12.6 Universal Design

When designing adaptive housing for changes and transformations of families, universal strategies is a necessary concept of

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[186] Ibid, 196.
[187] Ibid.
[188] Ibid, 198.
[189] Ibid, 199.

design in order for the environment to accommodate for all user needs and abilities.[190] This design concept is not the same as ADA requirements although they have similar strategies, but the primary objective of universal design to create space that is usable for anyone.[191] Universal design strategies are applied in all spaces especially in the bathroom which includes lowering sinks and providing knee clearance underneath, open baths or showers with seating, grab bars, and soft finish materials. In general spaces which includes, no steps in entry ways, ramps or elevator in the main circulation, wide doorways or opening, and wide corridors.[192] These are just some strategies that accommodate the needs and abilities of all users especially the older adults. These also promote aging in place by creating an environment that is more compatible for older adults.[193]

12.7 Reflection

The concept of flexibility in architecture is not a new concept, and there are infinite ways of achieving this idea. Adaptive housing, is a key factor to sustainability by promoting long term use and life cycle.[194] For the purpose of this research I will investigate only the principles and strategies in adaptability that best suits a high-rise typology for a multigenerational family

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[190] Dak Kopec and David Alan Kopec. *Health, sustainability, and the built environment*. Fairchild Books, 2009, 248.
[191] Ibid, 248-249.
[192] Kopec, *Health, sustainability*. 247.
[193] Ibid, 246.
[194] Beisi. "Flexible housing, compact city, 462.

in Honolulu, which includes strategies that are generally simple in its construction and ease of user intervention. So based on the observation from Schneider and Till, the most suitable approach would be design strategies that are considered 'hard' approaches, primarily because of the limited space and restrictions of being in a high-rise typology. The strategies that will be further explored in part of the design for the prototype at the later part of this research will consists of primarily the unit and the room level, particularly the low cost and noncomplex strategies. These strategies will be further explored in the design section.

12.8 Precedents

Songpa Micro Housing/ SsD

Figure 25: Songpa Micro Housing
Source: SsD, Songpa Micro-Housing, August 02, 2015. From: http://www.ssdarchitecture.com/works/residential/songpa-micro-housing/.

The Songpa Micro Housing designed by SsD in Seul, Korea is a housing that takes on the issues of urban density land cost and social values.[195] This is achieved by maximizing the use of space through flexible solutions, circulations that can transform to public spaces and walls that maximize floor area.[196]

Figure 26: Corridors transformation of function
Source: SsD, Songpa Micro-Housing, August 02, 2015. From: http://www.ssdarchitecture.com/works/residential/songpa-micro-housing/.

The corridors for example allows for daylighting to penetrate through and is flexible in use; making it a space that could be used for social gathering which is eminent throughout the building.[197]

[195] "Songpa Micro-Housing," SsD, August 02, 2015, , accessed January 12, 2017, http://www.ssdarchitecture.com/works/residential/songpa-micro-housing/.
[196] Ibid.
[197] Ibid.

Figure 27: Flexible components

Folding furniture that are integrated into the walls make it possible for the rooms to be able to adapt to the specific needs of the users. Similarly adjacent units can be joined together through bridging and or movable walls.[198] These building features allows for the occupants to have the opportunity to adjust their living conditions and are able to live in the units longer.

A House With 3 Walls, Shigenori UOYA, Miwako MASAKO & Takeshi IKEI

Figure 28: A House With 3 Walls

[198] Ibid.

Figure 29: First and Second Floor Plan
Source: Kyoto-Model: A House With 3 Walls / Shigenori UOYA Miwako MASAOKA Takeshi IKEI," ArchDaily, January 27, 2011, From: http://www.archdaily.com/106601/kyoto-model-a-house-with-3-walls-shigenori-uoya-miwako-masaoka-takeshi-ikei.

This house was designed in the city of Kyoto, Japan an interesting feature about this building is that it is composed of only three structural walls.[199] The significance of this is that it creates an open plan that allows for flexibility for various form of occupancy.[200]

[199] "Kyoto-Model: A House With 3 Walls / Shigenori UOYA Miwako MASAOKA Takeshi IKEI," ArchDaily, January 27, 2011, , accessed January 12, 2017, http://www.archdaily.com/106601/kyoto-model-a-house-with-3-walls-shigenori-uoya-miwako-masaoka-takeshi-ikei.

[200] Ibid.

Figure 30: Adaptability overtime

Figure 31: Seasonal flexibility
Source: Kyoto-Model: A House With 3 Walls / Shigenori UOYA Miwako MASAOKA Takeshi IKEI," ArchDaily, January 27, 2011, From: http://www.archdaily.com/106601/kyoto-model-a-house-with-3-walls-shigenori-uoya-miwako-masaoka-takeshi-ikei.

These diagrams display how the floor plan layout can change overtime to adapt to the changes of family size.[201] With the open floor plan it is easy to transform the spaces to adapt to the changes in the household, this is achieved through flexible methods such as light frame partitions, sliding shoji doors, Building components in this case are easily interchangeable and could be altered seasonally or overtime.[202]

Raku-Inkyo Adaptive Redevelopment, Suichi Matsumura et. al.

Figure 32: Raku-inkyo A existing

Figure 33: Raku-inkyo B existing

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[201] Ibid.
[202] Ibid.

Source: Matsumura, Shuichi, Kyoko Muraguchi, Seiji Kobata, Katsuhiko Ishizuka, Seiichi Fukao, and Yongsum Kim. *Development of Reusable Infill Systems for Elderly People's Living*. University of Tokyo, 2003.

Figure 34: Raku-inkyo A and B Existing floor plans

Source: Matsumura, Shuichi, Kyoko Muraguchi, Seiji Kobata, Katsuhiko Ishizuka, Seiichi Fukao, and Yongsum Kim. *Development of Reusable Infill Systems for Elderly People's Living*. University of Tokyo, 2003.

The Raku-inko renovation was a research project that was conducted by Suichi Matsumura from the University of Tokyo. The project objective was to use infill systems as an adaptive method, to transform the unit for an elderly occupant.[203]

[203] Matsumura, Shuichi, Kyoko Muraguchi, Seiji Kobata, Katsuhiko Ishizuka, Seiichi Fukao, and Yongsum Kim. *Development of Reusable Infill Systems for Elderly People's Living*. University of Tokyo, 2003.

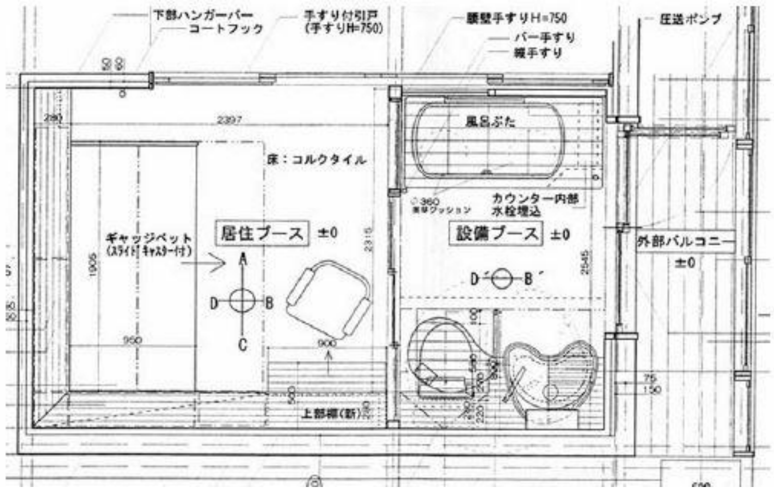

Figure 35: Raku-Inkyo C Plan

Source: Matsumura, Shuichi, Kyoko Muraguchi, Seiji Kobata, Katsuhiko Ishizuka, Seiichi Fukao, and Yongsum Kim. *Development of Reusable Infill Systems for Elderly People's Living*. University of Tokyo, 2003.



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Figure 36: Infill systems

Source: Matsumura, Shuichi, Kyoko Muraguchi, Seiji Kobata, Katsuhiko Ishizuka, Seiichi Fukao, and Yongsum Kim. *Development of Reusable Infill Systems for Elderly People's Living*. University of Tokyo, 2003.

The infill systems that were used in this case were wooden finishes that consists of other function like a handrail for example, light weight partitions that could be removed, light beds that can be easily moved, sliding doors, toilets that are covered with a table to conceal, a kitchen sink that is also a washing bowl, bath tub that can transform into a seating space, and folding doors that opens up the interior to the outdoor adding more space.[204]

Flexible Apartment, METAMOOREFOSE Studio

Figure 37: Folding partition

Source: Caroline Williamson. "A Flexible Apartment for a Young Couple in São Paulo." Design Milk. December 12, 2016. From: http://design-milk.com/a-flexible-apartment-for-a-young-couple-in-sao-paulo/.

[204] Ibid.

This project is designed by METAMOOREFOSE Studio for a couple in Sao Paulo, Brazil. The architects used a very simple flexible method to create flexibility within the unit, using a folding wall partition.[205] The use of the folding partition allows the space to be divided into two different rooms which creates privacy and may be used for a different function.

Multi-generational Housing Development in Freiburg, Pfeifer Roser Kuhn

Figure 38: Multigenerational Housing Development in Freiburg, Germany

[205] Caroline Williamson. "A Flexible Apartment for a Young Couple in São Paulo." Design Milk. December 12, 2016. Accessed January 13, 2017. http://design-milk.com/a-flexible-apartment-for-a-young-couple-in-sao-paulo/.

Figure 39: Light construction walls and plumbing location

Source: "MULTI-GENERATIONAL HOUSING," Regeneration: Model for Sustainable Inter-generational Living, From: http://sieplcoatesstudio.weebly.com/multi-generational-housing.html.

Figure 40: Diverse unit types
Source: "MULTI-GENERATIONAL HOUSING," Regeneration: Model for Sustainable Inter-generational Living, From: http://sieplcoatesstudio.weebly.com/multi-generational-housing.html.

The multigenerational housing in Freiburg, Germany is designed by Pfeifer Roser Kuhn to house various sizes of households. The method used in this project to achieve flexibility was the application of light construction wall.[206] This allows for adaptive units that could be adjusted to fit the needs of the divers users, which also promotes aging in place and multigenerational living.[207]

Via Verde, Grimshaw & Dattner Architects

Figure 41: Via Verde Housing Development

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[206] "MULTI-GENERATIONAL HOUSING," Regeneration: Model for Sustainable Inter-generational Living, , accessed January 13, 2017, http://sieplcoatesstudio.weebly.com/multi-generational-housing.html.
[207] Ibid.

Via Verde, designed by Grimshaw and Dattner Architects is an affordable housing complex located in New York, which consists of 222 housing units.[208]

Figure 42: 2 Bedroom complex
Source: "Via Verde / Grimshaw Dattner Architects." ArchDaily. March 10, 2014From: http://www.archdaily.com/468660/via-verde-dattner-architects-grimshaw-architects.

[208] "Via Verde / Grimshaw Dattner Architects." ArchDaily. March 10, 2014. Accessed January 13, 2017. http://www.archdaily.com/468660/via-verde-dattner-architects-grimshaw-architects.

Figure 43: 2 and 3 Bedroom complex
Source: "Via Verde / Grimshaw Dattner Architects." ArchDaily. March 10, 2014From: http://www.archdaily.com/468660/via-verde-dattner-architects-grimshaw-architects

The units are multistoried similar to the pile up concept which optimizes space vertically and allows for potential vertical flexibility. In addition the units could be joined to create a larger unit for a larger family size.

13. Bioclimatic

As mentioned earlier, along with demographic, social and economic changes, there are also changes in the climate that intensifies the impacts of the physical environment to the human health. In response to this matter, bioclimatic or climate responsive design is incorporated as one of the design principles.

Bioclimatic architecture refers to buildings that are inspired by nature and modifies the climate to achieve the most livable indoor environment.[209] All to provide a shelter that brings comfort, and promotes a sense of well-being for the occupants.[210] Climate has always been a design factor since man first built shelter to protect himself from the elements of the natural environment.[211] Architectural theorist Marc-Antoine Laugier argued in his writing of the *Essay on Architecture* that man wants nothing but shelter from the environmental conditions like the sun, rain or storm. He believed that a shelter is as simple as wood columns, perpendicular to the ground that supports a sloped roof of branches covered with leaves, and moss to prevent the sun or the rain from getting into the living spaces.[212] This concept is displayed prominently in vernacular architecture that could be found in all regions, which uses various design solutions to respond to the diverse climates.[213,214] Vernacular architecture are usually dwellings and other types of building that are responsive to the climate, built with available

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209 Victor Olgyay. *Design with climate: bioclimatic approach to architectural regionalism*. Princeton University Press, 2015. 15.

210 Ibid.

211 Ibid, 4.

212 Marc-Antoine Laugier. "An Essay on Architecture, trans." *Wolfgang and Anne Herrmann, Hennessey & Ingalls, Los Angeles* (1977).

213 Olgyay. *Design with climate,* 4-8.

214 David Lloyd Jones, Jennifer Hudson, and Tadao Ando. *Architecture and the environment: bioclimatic building design*. London: Laurence King, 1998, 14-17.

resources in the region. They are usually owner or community built with traditional tools to meet the specific needs, and is reflective of the values and culture of the people that created them.[215]

Towards the modern era, innovation and development in technology and building construction were very significant. The modern movement is known to have changed the way the society lives today through the exploration of new ideas, many architects would join this movement like Richard Neutra or Rudolph Schindler and especially Frank Lloyd Wright.[216] After the Second World War, modern architecture would really emerge bringing a style of architecture that would dominate the mid-twentieth century. This is called the “international style” which was a style that was given life from the Bauhaus school in Germany as defined by architect Walter Gropius in his book *The New Architecture and Bauhaus* (1935). The style became the identity of the modern movement, which would spread throughout the world including the U.S. where Mies Van de Rohe would popularize this style through his multiple designs like Farnsworth House in Plano IL., Crown Hall at the Illinois Institute of Technology and the Seagram Building in Chicago.[217] He would essentially influence other architects who

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[215] Paul Oliver*, Dwellings:The Vernacular House World Wide*, (New York, NY, Phaidon Press Inc. 2003) 14.

[216] Kenneth Frampton. *Modern Architecture: a Critical History*. (London: Thames and Hudson,
1985). *57*

[217] Ibid. 232

would promote the movement of the international style but most notable was Phillip Johnson who would design the Glass House in New Canaan, Connecticut that most resembles Mies' work.[218] Today we could probably say that the modern architecture following the Second World War brought a lot of unfavorable outcomes in relation to sustainability and social relations, which still affect us to this day. Some might say that midcentury modern architecture is against nature and the human aspect of it, often favoring technology like the automobile.[219] On the other hand, there were influential people, who began to think about the impacts that the built environment had towards the planet as well as the community. One of the more influential was writer, sociologist, and critic, Louis Mumford who believed that "the design of urban environment and its economic condition was less important in relation to nature and the cultural values of people."[220] This subject would be discussed in various influential books that he would write such as *Technics and Civilization* (1934), *The Culture of Cities* (1938), or *The Urban Prospect* (1968), and especially *The City in History: Its Origins, Its Transformation, and Its Prospects* (1961), which evaluates urbanization and really show his criticism to urban sprawl, but most importantly he began to evaluate further the social impacts of the urban development through comparison of historical civilization with the current. His ideas are labeled as

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[218] Ibid, 241.
[219] Jones. *Architecture and the environment.* 23.
[220] Lewis Mumford. "What is a City?". *Architectural Record 1*, 1937.

regionalist approach to urban design which would influence future urban designers, architects, planners, and other writers like Rachel Carson, Jane Jacobs, William Whyte and Ian McHarg who would continue to evaluate the impact or urbanization to the human health and the natural environment. Mumford's ideas would also influence the introduction of an architectural style called "critical regionalism" as labeled by architect Alexander Tzonis and Liane Lefaivre, and especially Kenneth Frampton who would really bring value to this concept."[221] In his writing, *Toward a Critical Regionalism: Six points of architecture of resistance* (1993)," Kenneth Frampton would discuss the implication of regionalist thinking in designing architecture. Here he highlights the significance of architecture being sensitive to its specific location through qualities like "topography, context, climate, light and tectonic form."[222]

Critical regionalism through Framton's perspective is reflected through works of various architects, starting from Le Corbusier to Luis Khan, Jorn Utzon, and Alvar Aalto and later Tadao Ando, whom are all masters or architecture and the use of materiality, form, light and the human experience, characteristics of the critical regionalism.[223,224] The ideas of the critical regionalism also emanates to other later architects who really explored the

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[221] Kenneth Frampton. "Toward a Critical Regionalism: Six points for an architecture of resistance." *Postmodernism: a reader* (1993): 268.
[222] Ibid.
[223] Ibid.
[224] Frampton. *Modern Architecture: a Critical History,* 324.

concept of integrating nature and architecture such as, Hasan Fatty, Bruce Goff, Herb Greene, Frei Otto, or Buckminster Fuller.[225] Although Critical regionalism

brought attention to the impacts that the built environment have to the planet and the social well-being, modernization was still too pervasive.[226] Innovation in technology, building construction, industrial manufacturing, automobiles, high-rises, elevators and air-conditioning all became characteristics of the modern and the postmodern life that we live today. Throughout the world societies continued to evolve, and as population grew, cities would emerge or further develop. The urban fabric grew bigger, the natural landscape would be reshaped for streets and highways that would make way for more cars and the modern culture that would replace the old.[227,228] Unfortunately the consequence of these events would lead to the high demand in energy, global warming, and unhealthy living environment.[229,230] The period following the Modernist era, became a generation that aimed to reshape the built environment as a reaction to the outcomes of modernization, this became the proponents to the emergence of *bioclimatic architecture*, a postmodern architectural style as labeled by

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[225] Ibid, 30.

[226] Jones. *Architecture and the environment*. 49.

[227] Frampton. "Toward a Critical Regionalism," 16.

[228] Ian L. McHarg, and Lewis Mumford. *Design with nature*. New York: American Museum of Natural History, 1969, 19.

[229] Jones. *Architecture and the environment*. 31.

[230] McHarg. *Design with nature*, 20-21.

architecture historian and critic Charles Jenks.[231] Bioclimatic thinking would focus on the overall performance of the structure, particularly its relation to the natural environment and its occupants,[232] similar concept and characteristics of the critical regionalist idea. The term bioclimatic is also interchangeable with term climate responsive design which both has similar meanings.

Bioclimatic design along with the regionalist concept is adapted by various architects of the postmodern era, and would continue to research and refine the concept of climate responsiveness and critical regionalism in architecture. Architects like Alexander Pike who would design the Autarkic House which a house prototype that incorporates passive design and new technologies used today like photovoltaic to reduce energy consumption to zero. Glenn Murcutt who would focus on the vernacular aspect of architecture in the rural parts of Australia., Mick Pierce, Charles Correa and countless other architects who would continue to practice these bioclimatic ideas today particularly Ken yeang who would research write multiple books on this subject and applying this concept on designing various built and unbuilt projects .

Ken Yeang is a Malaysian architect who studied in Cambridge University UK and focused much of his studies on master planning with

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[231] Jones. *Architecture and the environment*, 56.
[232] Ibid.

influences from notable architects like Frampton who explored theory of critical regionalism.[233] His doctoral thesis was focused primarily on the built environment and its relationship with nature, with a vision of developing an ecologically responsible architecture for the 21st century.[234] His work can be considered as a reaction to the urban development in the tropical context, where most of his studies and work were concentrated. In his years of practice, he acquired multiple projects which were mostly high-rise buildings in the tropical region where he developed most of the bioclimatic ideas, particularly on high-rise typology which he would eventually develop as the *bioclimatic skyscraper*.[235]

13.1 Bioclimatic High-rise

During the modern movement there was growth in the construction of tall buildings especially for the cities that were rapidly developing. This was more prominent after the second world war where a new form of architecture came to rise called the international style, which was adapted throughout every major city especially in the United States, where Meis van der Rohe applied the style.[236] With the innovation of technology, building construction and material fabrication, the high-rise was much easier to

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[233] Robert Powell, *Ken Yeang: Rethinking the Environmental Filter* (SIN: Landmark Books PTE LTP, 1989).

[234] Ken Yeang, et al. *Bioclimatic skyscrapers*. Artemis, 1994. 23.

[235] Hart, Sara. *Eco Architecture: The Works of Ken Yeang*. Edited by David Littlefield. UK: John Wiley & Sons.(2011). 11.

[236] Frampton. *Modern Architecture: a Critical History,* 231.

construct and as the population began to increase so did the demand for the high-rise typology. The innovation of construction has transformed the culture in the urban environment making it possible for people to live and work in the city skies. German architect like Ludwig Mies van de Rohe was a renowned architect who pioneered the glass façade high-rise building in the later part of the modern movement. His Bauhaus trained mind had pushed the idea of international style in all of his design, the most well-known of them all is the Seagram Building in 1958 which is often regarded to as the pinnacle of the modern high-rise architecture. There were other notable architects who would design high-rise in the modern movement but one architect stands out the most; Le Corbusier approached high-rise design in a different direction that was more sensitive to the natural environment, the cultural and social aspect of the built spaces, a concept that was different from the more predominant international style. The Unite d'Habitation, 1952 in Marseille, France for example was Corbusier's first large project. It stood at about 180 ft and consisted of 18 floors, what was unique about the building that made it stand out was the application of Corbusier's theory of human scale. He also incorporated into the design the concept of "Vertical garden city" which a system of integrating all goods and service with the dwelling units which responded to the needs of the residents and promoting self-sufficiency. The Unite d'Habitation is essentially a city within a city. To help achieve this, Corbusier redesigned the spatial arrangement of the units to something that was unlike the others. The building had units that spanned to each side of the building façade and had double height living spaces. It is through architects like Le Corbusier that would inspire the generation of architects in the postmodern era.

There are many architects in the 21st century that would develop the thought of human and environmental relationship with architectural design. A more recent architect and writer Ken Yeang would be one of the postmodern architects who would explore this idea further by focusing on the ecological and cultural elements into the architecture design. Ken Yeang's vision was to improve the living experience of the users through the concept of unification between the natural environment and the built space.[237] bioclimatic principles, a building design should be optimized to create a thermally comfortable environment. He achieved this through design principles that focused on climatic conditions and ecological integrations.[238] The popularization of the high-rise typology that was occurring mostly in the U.S. and the rapid urbanization of Southeast Asia would essentially influence him in developing a better model called the bioclimatic skyscraper.[239] A few of his design strategies will be considered in this research because of the climatic similarities that he has designed for.

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237 Ken Yeang, Alan Balfour, Ivor Richards, and Tengku Robert Hamzah. *Bioclimatic skyscrapers*. (Artemis, 1994). 21.

238 Ken Yeang, Alan Balfour, Ivor Richards, and Tengku Robert Hamzah. *Bioclimatic skyscrapers*. (Artemis, 1994). 23

239 Ibid. 19.

Today, bioclimatic or climate responsive design is being explored by multiple architects, and there are various approaches and methods in which this could be achieved. For this research I will look into investigating various methods that is most effective for Hawaiʻi's climate.

13.2 Responsive Design Process

There are various methods and strategies in which climate responsive design could be achieved, but what they have in common is that in order to achieve a bioclimatic building, it is necessary to follow an architectural design process based on an ecological perspective.[240] This research will adopt the similar schematic design process that is shared in the book *The Green Building Handbook* by Alison G. Kwok, which I find successful in providing a good basis on how to design a climate responsive architecture. The schematic design process consists of:

Schematic Design Process[241]

Defining the Problem
- Schema
- Intention
- Criteria
- Validation
- Prioritizing

Project Data
- Collection
- Site Analysis
- Site Selection

[240] Alison G. Kwock, and Walter T. Grondzik. *The Green Building Handbook: Environmental Strategies for Schematic Design*. First ed. (Oxford, UK. Elsevier, 2007). 7.
[241] Kwock,*The Green Building Handbook.*7-13.

Form Giver
- Daylighting
- Passive and Active strategies

Feedback Loop
Building Organization
Translational Space
Structure
Envelope
- Material
- Insulation

Climate Control System

Although the process is organized in a strategic way, the form finding of a building is not restricted to the order of which this process is laid out for as Kwock would note, "they can be executed with infinite variations,"[242] but also reciprocates with one another. The next section will briefly discuss the initial part of the design process as defined by Kwok, however, I briefly define only elements that I find significant in relation to this research. In addition, I will discuss various tools as mentioned by Kwok, which would assist in making the proper decisions that would improve the overall building performance. Lastly I would explore various measures to assess the thermal comfort of the environment.

Defining the Problem

To briefly explain, as defined by Kwok, understanding the parameters and the vision of a project is very important and should be established in the

[242] Ibid, 13.

very beginning of the design phases.[243] It is here that the overall concept and benchmarks of the project design, the goals, and the assumptions are established.[244]

Project Data

It is in this process where the composition of the building form begins. Understanding and evaluating the site is very important to for all architectural design, especially for a bioclimatic building which encompass passive systems. The condition of the microclimate, topography and other characteristics of the site like neighboring structures, informs the designer in making the most effective solutions.[245]

Form Givers

The building mass can be influenced by many factors depending on the design concept and intent. In design a bioclimatic architecture, the building mass would be influenced by the sun in reducing heat gains, optimizing wind ventilation and maximizing daylight.[246] Daylighting focuses on design strategies that maximize daylighting which is a significant element on creating a visually comfortable environment. At the same time

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243 Ibid.7.
244 Ibid, 8.
245 Kwock,*The Green Building Handbook*.9.
246 Yeang, Ken. *The Green Skyscraper*.205-212.

daylighting have psychological benefits.[247] This consist of properly sizing windows and or openings and other lighting strategies to fully optimize daylight.[248] Passive strategies refer to the use of natural elements to provide comfort in the indoor environment, such as natural ventilation or sun light for heating.[249] Active strategies on the other hand refer to mechanical systems to provide cooling and heating, like air conditioning.[250] However both can be integrated at the same time which is called a hybrid system.[251] This is a way to allow the building to responsive to certain conditions and could also allow control for users.[252]

Building Organization

This part of the process refers to the layout of programs in the building, this could influence or be influenced by the overall form of the building depending on the intent.[253] Programs could be organized based on orientation, social purposes, or optimizing the building performance.[254]

Transitional Spaces

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[247] Lisa Heschong. "Daylighting and human performance." *ASHRAE journal* 44, no. 6 (2002): 65.
[248] Kwock,*The Green Building Handbook.*9.
[249] Ibid.
[250] Ibid.
[251] Ibid.
[252] Ibid
[253] Ibid. 11.
[254] Kwock,*The Green Building Handbook.*11.

Transitional spaces in this case are circulation between spaces of a building.[255] The location of the circulation of a building is important because it may influence the over mass of a building. The location of the circulation may also influence how the sun will impact the building surface which would affect the internal comfort.[256] The circulation mass in this case may function as a barrier.

Passive and Active Strategies

The building climate control systems refer to the passive and/or active techniques to respond to a certain climatic condition.[257] Passive strategies refer to using natural elements along with creative solutions from the architect, to respond to the micro climate of the building site.[258] This refers to proper configuration and placement of building components such as walls, windows, overhangs, or shading devices.[259] Active Strategies on the other hand refer to the mechanically operated systems such as heating, ventilation and air conditioning systems (HVAC) to provide thermally comfortable environment. Sometimes the two are combined to create a hybrid system; passive and active strategies work together, usually between the building envelope and the HVAC systems to respond to climatic

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[255] Ibid.

[256] Yeang, Ken. *The Green Skyscraper*: *The Basis for Designing Sustainable Intensive Buildings*. Munich: Prestel, 1999.208.

[257] Ibid, 10.

[258] Ibid.

[259] Ibid.

conditions.[260] The operation of a hybrid system may be manually adjusted by occupants or computer operated to automatically employ the systems based on the climate conditions.[261]

Envelope

The envelope of a building is generally composed of specific materials and insulation.[262] Certain properties of the materials and insulation of an envelope impacts the amount of heat that from the exterior environment into the indoor spaces.[263] Which affects considerably the thermal comfort of a building, therefore choosing the proper materials is essential in providing a thermally comfortable indoor environment.[264] The envelope could also include shading devices along the façade like louvers or screens to prevent solar radiation or rain from entering the building.

13.3 Thermal Comfort

As defined by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), in the book Standard 55-2013, Thermal Environmental Conditions for Human Occupancy (ASHRAE 55), thermal comfort refers to the "the condition of mind that expresses satisfaction with

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[260] Ibid
[261] Ibid.
[262] Kwock,*The Green Building Handbook*.12.
[263] Ibid.
[264] Ibid.

the thermal environment and is assembled y subjective evaluation."[265] This is often how building spaces are measured by in reference to human comfort and the temperature. There are various factors that impact the thermal comfort of a person which includes the "*metabolic rate*" or the persons activity level, "*clothing insulation*" which refers to the type of clothing that a person is wearing, "*air temperature*," which is the atmospheric temperature, "*radiant temperature*," which is temperature that radiates from a surface or material, "*air speed*," which is wind, and "*humidity*" which is the moisture content in the air.[266] All of which affects how the occupants perceive comfort in an environment. The dependency towards air conditioning also affects how a person can perceive thermal comfort in comparison to a naturally cooled environment.

[265]A. S. H. R. A. E. Standard "Standard 55-2013—Thermal Environmental Conditions for Human Occupancy." *ASHRAE Inc., Atlanta, GA* (2013).
[266] A. S. H. R. A. E., "Standard 55," 2-4

Bioclimatic Chart

Figure 44: Bioclimatic Chart, for U.S. Moderate Climate Zone

To better understand the most optimum strategy for a bioclimatic architecture, it is best to utilize the bioclimatic chart (Figure 44) to determine how to respond to certain climatic conditions. The bioclimatic chart was developed by Victor Olgyay through his study in his book *"Design with Climate- Bioclimatic Approach to Architectural Regionalism."* It displays the impact of climate towards comfort particularly in shade in moderate climates.[267] The bioclimatic chart is composed of a comfort zone; shaded in the center, and the climates around it; determined by dry-bulb temperature and relative humidity, is represented by lines which imply suggested measures needed to be in the comfort zone.[268]

To briefly explain, if the climate condition falls above the comfort zone, wind is needed at specific speed; feet per minute (fpm).[269] If the temperature is high and humidity level is low, evaporative cooling would be the suggested strategy.[270] The shading line directly below the comfort zone marks the temperature and above when shading is necessary.[271] Everything below the line suggests the use of solar radiation to respond to lower temperature.[272]

Building Simulation Software

To analyze site and measure the overall effectiveness of the design strategy, computer building simulation software will be used throughout the design process. Software simulation tools that will be used include DIVA for Rhino Designbuilder Software.

DIVA for Rhino is a tool that was developed at the Graduate School of Design at Harvard University and is now distributed and developed by

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[267] Olgyay. *Design with climate,* 22.
[268] Ibid, 22.
[269] Ibid.
[270] Ibid.
[271] Ibid.
[272] Ibid.

Solemma LLC.[273] It is a tool used to analyze daylighting and energy of a building or space, allowing architects and designers to optimize window openings, glazing and shading devices.[274] Number of analysis that can be gathered includes "radiation maps, photorealistic renderings, climate-based daylighting metrics, annual and individual time step glare analysis, LEED and CHPS daylighting compliance, and single thermal zone energy and load calculations."[275]

Designbuilder software is a tool used to assess the overall building performance, including building energy and comfort.[276] It is able to analyze thermal conditions, size heating and cooling systems, environmental performance, thermal comfort, solar heat gains, surface temperature, passive performance such as thermal mass, and also computational fluid dynamics for ventilation.[277]

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[273] Niemasz Jeff. DIVA for Rhino: Environmental analysis for buildings. 2017. Accessed February 2, 2017. http://diva4rhino.com/.

[274] Ibid.

[275] Ibid.

[276] "Designbuilder Software Energy Plus Simulation." DesignBuilder Software. Accessed February 2, 2017. https://designbuilder.co.uk/simulation/.

[277] Ibid.

13.4 Designing for Hawai'i

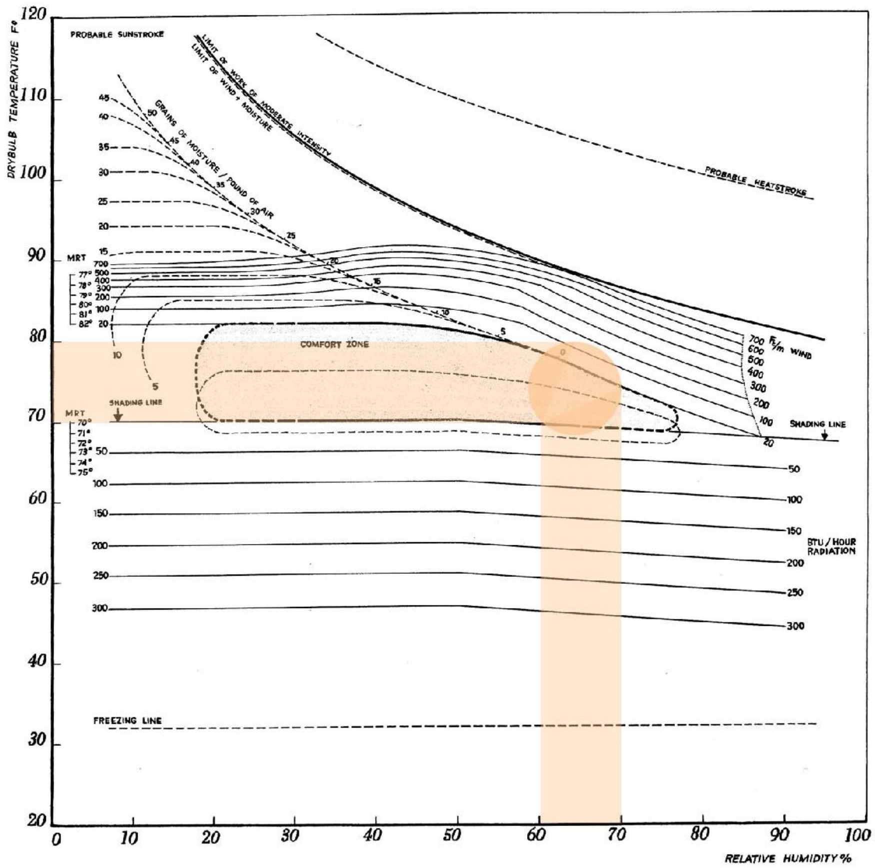

Figure 45: Bioclimatic Chart, Hawaii Climate Conditions

In Hawaii where temperature average ranges from 70-85°F and humidity level from 65–70%[278]; the condition falls generally on the comfortable zone under the shade, however this is not always the case for the indoor environment, sometimes the space lacks adequate ventilation or shading which alters the climatic condition inside. In Hawaii if the indoor temperature is higher than the outdoor temperature, natural ventilation is the suggested strategy to bring comfort.

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[278] S. Wilcox and W. Marion. 2008. *User's Manual for TMY3 Data Sets*, NREL/TP-581-43156. April 2008. Golden, Colorado: National Renewable Energy Laboratory.

The tropical climate of Hawai'i gives multiple opportunities for creating a bioclimatic architecture. Primarily because of its already temperate climate along with the trade winds, that allow for multiple effective passive strategies.[279] However there are some challenges that occur, such as overheating due to lack of ventilation, too much heat gains, climate change, high humidity and unpredictable wind, that could impact the comfort in the indoor environment. Effective strategies include protection from the sun, maximizing natural ventilation and or a hybrid systems.[280]

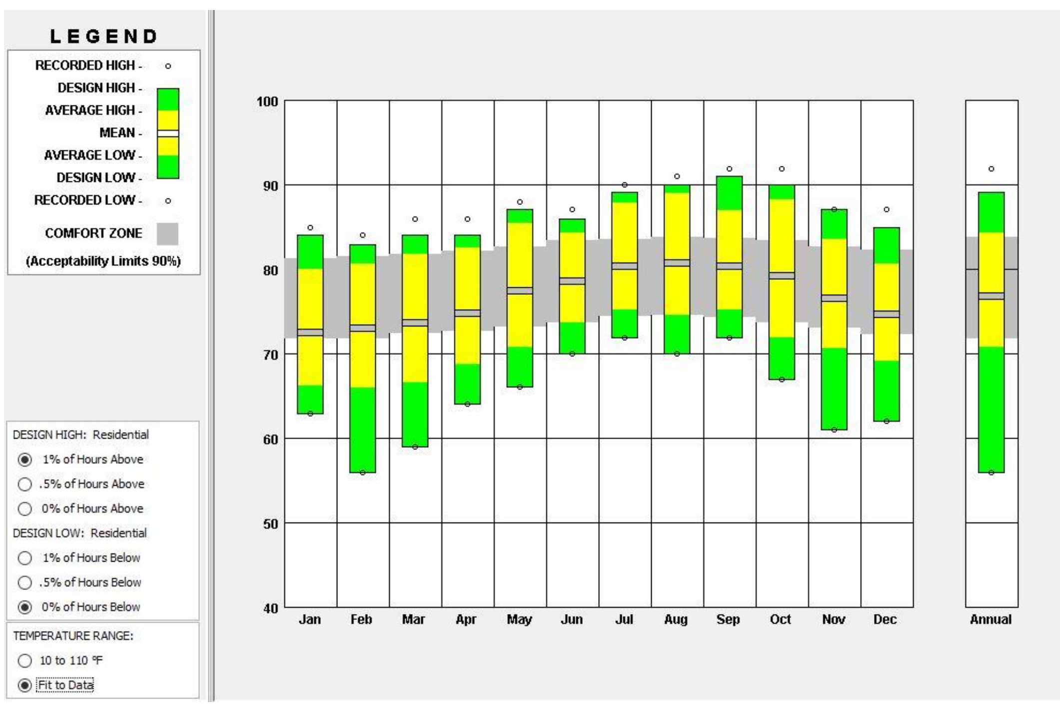

Figure 46: Hawai'i Temperature Range

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[279] James Furuhashi, et al. *Field Guide for Energy Performance, Comfort, and Value in Hawaii Homes.* Ed. 1.0. ed. Honolulu]: State of Hawaii, Dept. of Business, Economic Development & Tourism, Energy, Resources & Technology Division, 2001. 9.

[280] Ibid.

Natural Ventilation

Cooling is the common need for buildings in Hawaiʻi because of its climate region.[281] As mentioned previously, the average temperature in Hawaiʻi ranges between 70-85°F (Figure 46) and an average humidity of 65–70% throughout the year, which falls under the comfortable zone (Figure 45). This is prevalent especially in the spring and fall seasons. In addition, the trade wind from the north east brings a cool breeze during the spring seasons (Figure 47). Therefore Natural ventilation (exchange between the cooler outdoor air temperatures with the warmer indoor air temperature.[282]) would be the most effective passive strategy in achieving comfort.

[281] Furuhashi, *Field Guide for Energy.* 9.
[282] Ibid*,* 47.

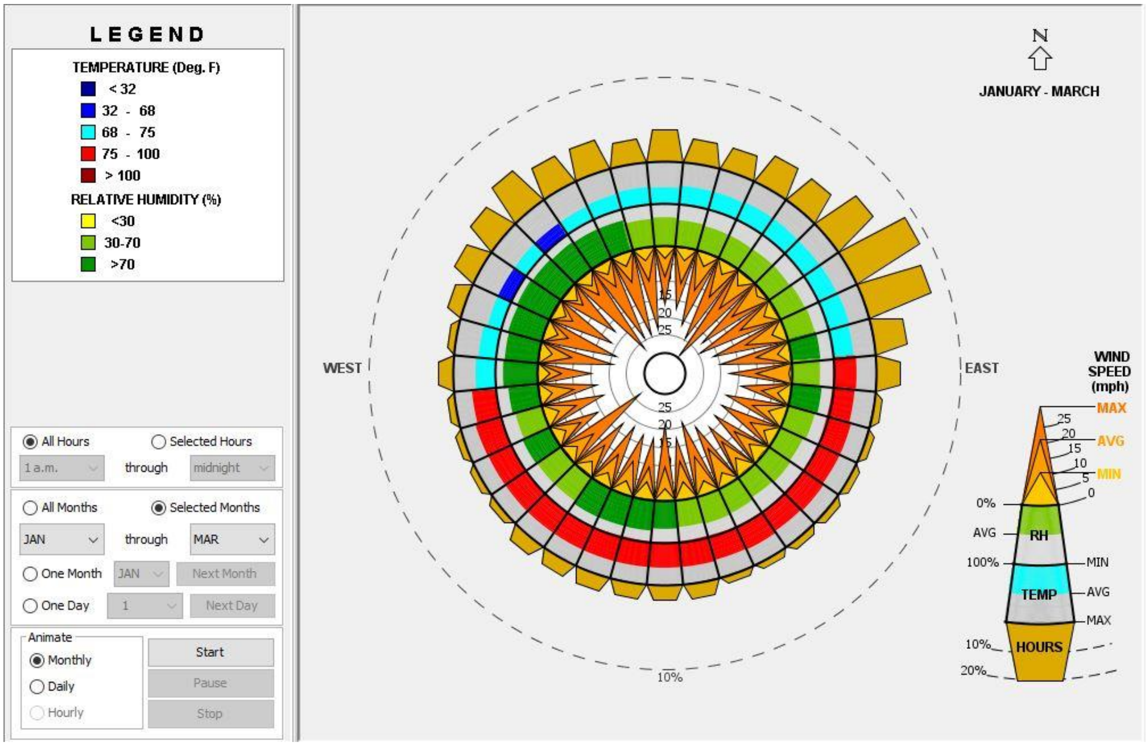


Figure 47: Hawai'i Wind Rose

13.5 Precedents

Menara Mesiniaga, Malaysia, Ken Yeang

Figure 48: Menara Mesiniaga, Malaysia, Ken Yeang
Source: "AD Classics: Menara Mesiniaga / T. R. Hamzah & Yeang Sdn. Bhd." ArchDaily. September 28, 2015. From: http://www.archdaily.com/774098/ad-classics-menara-mesiniaga-t-r-hamzah-and-yeang-sdn-bhd.

The Menara Mesiniaga is a highrise building designed by Ken Yeang for IBM's Malaysia Headquarter. Ken Yeang designed this building using bioclimatic principles in both interior and exterior of the building.[283] Yeang, took highly in consideration the impacts of the micro climate and optimized for passive systems.[284] There are two major bioclimatic design strategies in this building which is the building screen and the sky courts.[285]

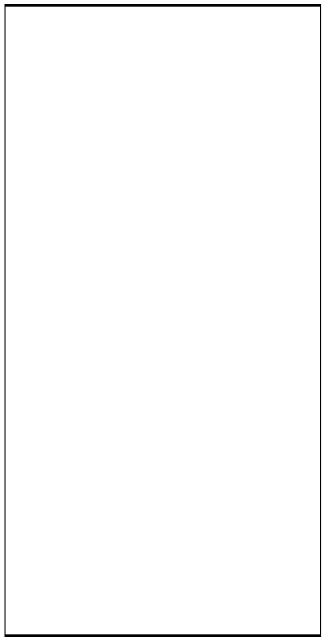
[283] Ken Yeang et al. *Bioclimatic Skyscrapers* (London: Artimis, 1994), 59.
[284] Ibid.
[285] Ibid.

Figure 49: Desing Concept Sketch

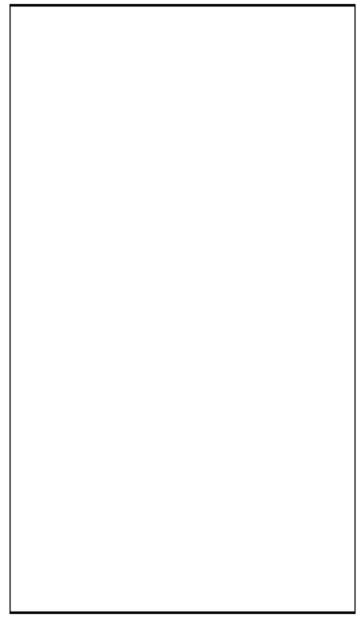
Figure 50: Sky Garden Diagram

Figure 51: Sun Shades Diagram

Source: Ken Yeang et al. *Bioclimatic Skyscrapers* (London: Artimis, 1994), 59-63.



A



B

Figure 52 A & B: Shading Device Detail

Source: Ken Yeang et al. *Bioclimatic Skyscrapers* (London: Artimis, 1994), 59-63.

The overall concept the design (Figure 49) is to create a low energy and comfortable highrise office building in the tropics by incorporating bioclimatic features.[286] The building façade is composed of sun shade (Figure 51) that is designed based on the condition of the sun responding to its path.[287] The building is also unique for its vertical gardens (Figure 50 & Figure 51) which creates social spaces and also provides vegetation which decreases the solar heat gains and most importantly maximizes the use of natural ventilation throughout the building.[288]

Federal Building, San Francisco, Morphosis

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[286] Yeang. *Bioclimatic Skyscraper.* 59-63.
[287] Ibid.
[288] Ibid.

Figure 53: Federal Building, San Francisco, Morphosis
Source: "San Francisco Federal Building: Building a Model for Civic Sustainability ." Morphosis. From: http://www.morphosis.com/architecture/12/.

The Federal Building in San Francisco was designed by Morphosis, the building has won multiple awards for its sustainable qualities.[289] The primary bioclimatic strategy that is applied in the building is the use of natural ventilation for passive cooling.

[289] "San Francisco Federal Building: Building a Model for Civic Sustainability ." Morphosis. Accessed January 27, 2017. http://www.morphosis.com/architecture/12/.

Figure 55: Cross ventilation Diagram

Figure 54: Skip Stop Elevator

Figure 56: Air Space Above Central Offices

Figure 57: CFD Simulation

Source: "San Francisco Federal Building: Building a Model for Civic Sustainability ." Morphosis. From: http://www.morphosis.com/architecture/12/.
" San Francisco Federal Building." NaturalWorks. From: http://www.natural-works.com/projects/sffed.php.

To maximize natural ventilation, the architects used an automated window that adjusts itself to allow for natural ventilation when needed. This is assisted by the design of the air space above the central office rooms, allowing for cross ventilation to flow through one side of the building to the other. In addition, skip stop elevators were used to not only improve social interaction, it also assist cross ventilation by increasing the ceiling height.[290]

CH2 Melbourne City Council House 2, DesignInc

Figure 58: City Council House 2, Melbourne, DesignInc
Source: "CH2 Melbourne City Council House 2 / DesignInc." ArchDaily. June 29, 2013. From: http://www.archdaily.com/395131/ch2-melbourne-city-council-house-2-designinc

The City Council House 2 (CH2) is designed by DesignInc in the city of Melbourne with a goal to be climatically responsive and to improve the relation between the city and nature.[291]

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[290] "Projects San Francisco Federal Building." NaturalWorks. Accessed January 27, 2017. http://www.natural-works.com/projects/sffed.php.

[291] "CH2 Melbourne City Council House 2 / DesignInc." ArchDaily. June 29, 2013. Accessed January 13, 2017. http://www.archdaily.com/395131/ch2-melbourne-city-council-house-2-designinc.

Figure 59: Daytime and Night time Bioclimatic Strategies
Source: "CH2 Melbourne City Council House 2 / DesignInc." ArchDaily. June 29, 2013. From: http://www.archdaily.com/395131/ch2-melbourne-city-council-house-2-designinc

In attempt to achieve zero emission, the architects applied a building façade screen particularly fins which responds to the solar path.[292] In addition to the building screen the architects created a system that helps to provide a thermally comfortable indoor environment. Using wind turbines, energy is generated to assist with extracting hot air from the inside, chilled panels are then incorporated on the ceiling to radiate cool temperature.[293] Floor vents that are controllable, brings in 100% fresh air through vertical

[292] Ibid.
[293] Ibid.

ducts, which improves the indoor air quality[294]. At night the windows open automatically to allow ventilation, creating night purge or night cooling, which is then absorbed by the concrete ceiling mass, removing the heat absorbed during the day.[295]

Newton Suites, WOHA

Figure 60: Newton Suites, Singapore, WOHA
Source: "Newton Suites Residential Tower | Newton Suites Residential Tower Presentation Panels." Archnet. From:. http://archnet.org/sites/6477/publications/2232.

[294] Ibid.
[295] Ibid.

The Newton Suites in Singapore is designed by WOHA, it is a 36-storey apartment highrise that explores design solutions that promotes a more sustainable living.[296]

Figure 61: Building Shading Device

Figure 62: Building Section; Lanai Sky Gardens

Source: "Newton Suites Residential Tower | Newton Suites Residential Tower Presentation Panels." Archnet. From:. http://archnet.org/sites/6477/publications/2232.

The bioclimatic methods applied in the design of the highrise consist of sun shading device (Figure 61) that shades primarily the unit windows and the external walls which reduces solar heat gains, naturally ventilated and lit lobbies that are along the main corridors, and sky gardens and lanai's (Figure 62) that extrudes out of the building façade which are community

[296] "Newton Suites Residential Tower | Newton Suites Residential Tower Presentation Panels." Archnet. Accessed January 13, 2017. http://archnet.org/sites/6477/publications/2232.

spaces that functions also as an overhang that shades the building façade and reduces heat gains through vegetation surfaces. [297]

Moulmein Rise, Singapore, WOHA

Figure 63: Moulmein Rise, Singapore, WOHA
Source: "No 1 Moulmein Rise On-site Review Report." Archnet. From: http://archnet.org/publications/1706.

The Moulmein Rise in Singapore was designed by WOHA, is 28 storey apartment building which consists of 48 units.[298] The building façade obtains various strategies of bioclimatic solutions, that allows for a sustainable lifestyle that embraces the response to the climatic conditions.

[297] Ibid.

[298] "No 1 Moulmein Rise On-site Review Report." Archnet. Accessed January 17, 2017. http://archnet.org/publications/1706.

Figure 64: Pixelated Building Screen

Source: "No 1 Moulmein Rise On-site Review Report." Archnet. From: http://archnet.org/publications/1706.

Figure 65: Bay Window; Monsoon Window

Figure 66: Penthouse with monsoon windows and high ceiling

Figure 67: Operable Bay Window with Monsoon window

Figure 68: Bay Window; Monsoon Window with Internal Blinds

Source: "No 1 Moulmein Rise On-site Review Report." Archnet. From: http://archnet.org/publications/1706.

A

B

Figure 69 A & B: Bay Window; Monsoon Window Detail Sections

Source: "No 1 Moulmein Rise On-site Review Report." Archnet. From: http://archnet.org/publications/1706.

The bioclimatic strategies use in the building design are the use of building screen (Figure 64) and also horizontal overhangs, the screen functions as a sun shading device which is pixelated to permit daylighting for the interior spaces.[299] The most interesting solution that was used in the building design was the "monsoon window (Figure 65)" which were inspired

[299] "No 1 Moulmein Rise On-site Review Report." Archnet. Accessed January 17, 2017. http://archnet.org/publications/1706, 4.

by the vernacular Malaysian, Indonesian, and Vietnamese traditional homes.[300] The purpose of the monsoon window is to provide passive cooling particularly when it is raining while at the same time, preventing water from entering.[301] Additionally, the windows are operable (Figure 67), which helps to provide full cross ventilation of the units. The high ceiling (Figure 66) also adds to the cooling effect by bring the hot air higher up.[302]

Oasia Hotel Downtown, Singapore, WOHA

Figure 70: Oasia Hotel Downtown, Singapore
Source: "Oasia Hotel Downtown / WOHA." ArchDaily. December 06, 2016. From: http://www.archdaily.com/800878/oasia-hotel-downtown-woha.

[300] Ibid, 6.
[301] Ibid.
[302] Ibid.

The Oasia hotel in Singapore is considered a "tropical living tower," which is demonstrated by its vertical gardens that are along its façade and its perforated building screen and its vertical sky gardens.[303]

Figure 71: Oasia Hotel Downtown Building Section
Source: "Oasia Hotel Downtown / WOHA." ArchDaily. December 06, 2016. From: http://www.archdaily.com/800878/oasia-hotel-downtown-woha.

[303] "Oasia Hotel Downtown / WOHA." ArchDaily. December 06, 2016. Accessed January 18, 2017. http://www.archdaily.com/800878/oasia-hotel-downtown-woha.

A. B.

Figure 72 A & B: Sky Gardens

Source: "Oasia Hotel Downtown / WOHA." ArchDaily. December 06, 2016. From: http://www.archdaily.com/800878/oasia-hotel-downtown-woha.

The perforated building screen wraps around the building façade provides shading from the very hot tropical sun to reduce heat gains. At the same time it allows daylighting to enter through which naturally lights the interior spaces.[304] The other unique element about the building is its use of sky garden, not only does the sky garden provides social spaces vertically, it also creates an opportunity for landscaping or gardens which reduces the direct impact of the sun. Similarly the sky gardens maximize natural ventilation throughout the building in a vertical manner.[305]

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[304] Ibid.
[305] Ibid.

14. Biophilic Design

Going to the theory of critical regionalism the relationship with humans and the natural environment is symbiotic. Capturing the concept of the healing properties that the natural environment awards to the human mind and body, into the built space is called *biophilic design*.[306] Therefore, when designing bioclimatic architecture, similar to Yeang it is necessary to incorporate nature into the built spaces.[307] Biophilic design in this case, is interrelated to the characteristics of the bioclimatic principle, primarily because of the integration of the natural environment into the living spaces such as natural ventilation and daylighting. However, aside from that biophilic design ensures that ecological elements are integrated into the building design such as vegetation or gardens, which is achieved through design solutions like sky courts / lanais or green facades, the use of natural materials, and framing the natural landscapes of the site. Incorporating biophilic elements into the design process is necessary because it offers various health benefits to the occupants.

14.1 Health Benefits

Today we can all agree that nature has positive influences to the human health. Some of the health benefits that biophilic design have for

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[306] Stephen R. Kellert, et al. *Biophilic Design : The Theory, Science, and Practice of Bringing Buildings to Life*. Hoboken, N.J.: Wiley, 2008.preface.

[307] Yeang, *The green skyscraper.* 11.

example is that contacts with nature, including direct contacts like gardens or sunlight, and indirect contacts like interior finish materials or pictures, are discovered to improve the healing process of people from being ill or from surgery.[308] Also it is found that people living next to or near an open space even exposure to little amounts of vegetation in both urban or rural context, have less health and social concerns.[309] In the work environment, offices that have natural elements like daylighting or natural ventilation have workers that are more productive, motivated and less stressed.[310] In addition, having contact with nature improves the overall neurological functions like thinking, learning, or memorizing.[311] Furthermore, children who were exposed to the natural environment grow and mature much healthier than those who lack the contact with the natural environment.[312]

It is clear that contact with nature have positive impacts to the human health, therefore It is essential to include biophilic elements into the design criteria. To achieve this there are design elements as discussed in the book *Biophilic Design* by Stephen Kelert, Judith Heerwagen and Martin Mador, that outlines the basic strategies that could be incorporated in designing an environment.

14.2 Biophilic Design Elements

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[308] Kellert. *Biophilic Design*, 4.
[309] Ibid.
[310] Ibid.
[311] Ibid.
[312] Ibid

There are six general elements that characterize biophilic design, this includes environmental features, natural shapes and forms, natural patterns and process, light and space, place based relationships, and evolved human nature relationships.[313] However, for the purpose of this dissertation, biophilic design is translated to the direct integration of natural elements and materials into the built form. Therefor the elements of biophilic design that will be further elaborated include the environmental features, natural shapes and form, and light and space.

Environmental Features

Environmental features are the most obvious of the six elements that can be easily applied to the design of an environment. This includes characteristics such as color using earth tones, water incorporated in features like fountains; air which prefers generally to natural ventilation, sunlight that can be achieved through optimizing daylighting, plants that can be incorporated in gardens, animals which comes with the application of gardens and/or open spaces and may also be representative elements like wall art or sculptures, natural materials that can be applied to the building finishes, and landscapes that can either be a view from the window or the landscape that is integrated on the building site.[314]

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[313] Ibid, 6.
[314] Ibid, 7-8.

Natural Shapes and Forms

The natural shapes and form elements refer to the representations and simulations of nature into the built space. This refers to botanical motifs; shapes, forms and patterns resembling plants, trees, and other vegetation applied on building finishes.[315] Tree and columnar support, relating to the building materials like wood, or columns that replicate treelike forms.[316] Shells and spirals, which refers to the imitation of invertebrate creatures primarily shells and spiral forms, translated onto the building skin or interior finishes.[317] Organic shapes and lines, which are natural shapes and lines that are visible in the natural world, often are elements that naturally flow like ripples of the water or the curves on trees.[318] Lastly is biomimicry, which refers to imitating nature's function as a design concept, such as the structural strength or bioclimatic properties of shells or hives incorporated into the design.[319]

Light and Space

Light and space is very straight forward, referring to the integration and the configuration of light and space which is described through characteristic qualities that are essential for both. In lighting, important qualities include the use of natural light or daylighting in the built

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[315] Ibid, 8.
[316] Ibid.
[317] Ibid.
[318] Ibid.
[319] Ibid.

environment, which was previously described as essential to the human health.[320] This could be achieved through building components such as windows, light wells, or solar tubes. Filtered or diffused light is a quality of lighting that enhances the sunlight to reduce the visual discomfort of glare; this could be achieved through reflective ambient light or building screens.[321] Light and shadow is another quality that embraces the value of the contrast between dark and light, creating a visual comfort within the building or the landscape surrounding.[322] Warm lighting is a quality that improves the sense of comfort and security in the environment.[323] Qualities that are significant in space, include spaciousness, referring to the openness of the environment which creates a relation between nature and the indoor environment.[324] Spatial variability, is a quality that embraces emotional and neurological inspiration, this is achieved in an organized layout.[325] Space as shape and form is where space is creatively manipulated to represent shapes or form, which if done properly, create an aesthetically pleasing environment that promotes interest, curiosity, exploration, and discovery.[326] Spatial harmony, which is a quality that refers to the overall unity of the configuration of

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[320] Ibid, 11.
[321] Ibid.
[322] Ibid.
[323] Ibid.
[324] Ibid.
[325] Ibid.
[326] Ibid.

spaces and other elements, this is generally balance between light, mass, scale, and configuration of space.[327]

14.3 Precedents

Sky Courts, Menara Mesiniaga, Ken Yeang

The sky court is a building element that is applied in various built and unbuilt projects. Skycourts are referred to as transitional or common spaces in a high-rise typology.[328] These spaces are similar to courtyard spaces applied in a vertical context, they are spaces that function as community spaces, which allows for flexibility in use, and potential transformation for additional

[327] Ibid.
[328] Yeang. *Bioclimatic skyscrapers*, 25.

programs.[329] Most significantly in this case, it is a design strategy to implementing vegetation or gardening for the occupants and also providing a visual opportunity for the natural environment such as landscapes.[330]

Home Farm, SPARK

The “home farm,” is a conceptual project designed by SPARK to house the older population of Singapore. A unique aspect of the building design is the integration of farming throughout the building. There are two types of farms envisioned in the design, which includes aquaponics farming along the facades of the building and soil-based farming located on horizontal surfaces including the rooftop.[331] The occupants become involved in the

[329] Ibid.
[330] Ibid.
[331] "SPARK Proposes Vertical Farming Hybrid to House Singapore's Aging Population," ArchDaily, November 30, 2014, , accessed January 25, 2017, http://www.archdaily.com/573783/spark-proposes-vertical-farming-hybrid-to-house-singapore-s-aging-population-2.

work needed for the farms which may include planting, harvesting, sorting, packaging, tours and sales on site.[332]

PARKROYAL on Pickering,WOHA

[332] Ibid.

Figure 73: PARKROYAL on Pickering

Figure 74: Comon Floor Plan

The PARKROYAL on Pickering in Singapore was designed by architects WOHA. The building is a hotel that embraces the idea of 'garden city.'[333] This high-rise hotel is designed with levels of sky gardens which are covered

[333] "PARKROYAL on Pickering / WOHA." ArchDaily. April 22, 2013. Accessed January 25, 2017. http://www.archdaily.com/363164/parkroyal-on-pickering-woha-2.

with vegetation (Figure 73).[334] The architects oriented the building layout so that each guest room of the hotel including the community spaces such as the swimming pool area are situated north away from the direct impact of the low angle sun, and also to have a direct visual access to the sky gardens.[335] The architects created an environment that really captures the relationship between the nature and the built space.

Figure 75: View from Guest Room

Figure 76: View from Bathroom

The windows and glazing from the guest rooms offer a view of the natural environment on the sky gardens along with the landscape beyond, and sometimes offering a direct contact with nature right outside of the window (Figure 75,Figure 76).[336]

[334] Ibid.
[335] Ibid.
[336] Ibid.

Figure 77: Interior Finish at Guest Bedroom

Figure 78: Interior Finish at Common Room

Moreover, the use of natural material is obvious throughout the building interior, wood finish is prominent in all the guest rooms and also throughout the common spaces which offers a warm and natural look.[337]

Figure 79: Water features along Corridors

Figure 80: Water Features along Lobby Corridors

There is also an Integration of water features particularly in the common areas such as along the edges of the primary corridors and the public spaces (Figure 79 & Figure 80). [338]

[337] Ibid.
[338] Ibid.

Figure 81: Spiral Staircase

Figure 82: Organic Formwork of the Facade and Ceiling

Figure 83: lighting at Public Spaces

Figure 84: Daylighting and Surface Shadows

Throughout the building it is obvious that the use of natural shapes form and lines was a significant aspect of the design of this building. There are visible components that clearly illustrate the application of organic shapes, form and lines such as the layers of building slabs along the public areas which, like contour lines, reflect an organic geometry; curvy and dynamic replicating something like layers of earth (Figure 82).[339] In addition, building

[339] Ibid.

components such as the spiral staircase enhances the organic concept that the architects was trying to achieve (Figure 81).

Another quality that further complements the relation between the natural and the built environment is the use of light. In the building it is clear that warm lighting was used, visible throughout the common and public spaces. In addition, daylighting was maximized with the help of glazing or curtain walls, and more importantly, the composition of the building form creates a play between dark and light, which results to a complimentary contrast of light and shadow (Figure 84).

Figure 85: Openness of the Lobby Spaces

Figure 86: Openness of Public Spaces

LEGEND

1 SKYGARDEN
2 ROOF TERRACE
3 GUESTROOMS
4 CABANAS
5 SWIMMING POOL
6 PREFUNCTION LOBBY
7 CONFERENCE ROOM
8 URBAN VERANDAH
9 HOTEL PASSAGEWAY
10 BACK OF HOUSE

Figure 87: Building Section

The spatial organization and variation is also an element that adds to the biophilic quality of this building. The high ceilings on the public areas and the variation of room layout and volume create an organic and easy transition between these spaces,[340] and with the combination of creative use of light form and space; promotes a sense of curiosity, exploration and discovery for the occupants.[341]

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[340] Kellert. *Biophilic Design*, 4
[341] Ibid.,

The architect clearly achieved to create an interrelationship between the natural and the built environment, this is clear throughout the building as previously assessed. In this precedent, the architect used a combination of qualities that achieve biophilic design; vegetation, landscape, water, light, geometry, and space.

15. Design Matrix

Adaptive Design				
Building Level	Vertical Addition	Horizontal Addition	Common Circulation	Slack Spaces
Unit Level	Neutral Rooms	Circulations	Joining Rooms	Joining + Dividing Units
	Multiple Entrances	Shared Spaces		
Room Level	Connections Between Rooms	Collapsible Furniture	Operable Walls	
Building Construction	Assembly	Clear Spans	Horizontal Services	Vertical Services

Bioclimatic Design				
Project Data/ Site Analysis	Solar Analysis	Wind Analysis	Surrounding Elements	Topography
Form Givers	Sun Path	Wind Direction	Programmatic Organization	
Transitional Space	Location	Type		
Envelope	Walls	Roof	Floors	Fenestrations

Climate Control Systems	Shading Devices	Natural Ventilation System	HVAC	Hybrid System

Biophilic Design				
Environmental Factor	Color	Water	Sunlight	Vegetation
	Landscape			
Natural Shapes	Botanical Motifs	Trees + Columns	Shells + Spirals	Organic Shapes + Lines
	Biomimicry			
Light	Daylight	Filtered or Diffused Light	Light + Shadow	Warm Light
Space	Spaciousness	Spatial Variability	Space as Shape + Form	Spatial Harmony

16. Design Criteria Evaluation

The purpose of this evaluation is to assess the health benefits of the proposed design criterion, which is composed with design principles that would guide the design of a residential high-rise, focusing on improving the quality of life for the occupants, especially for older adults. To further evaluate the level of healthiness that the design criterion imposes, it will be compared to the blue zone elements. The purpose of this evaluation is to determine whether the design principles have values that promote healthy behavioral characteri+110stics like the blue zone, which in turn encourages longevity.

16.1 Blue Zones

The blue zone is a term that Dan Buettner, an explorer and author for the national Geographic and his research team created to name a group of places around the world that has majority of its people living above 100 years or centenarians, which is about decade longer than the rest of the world. These blue zone places practically have better health than any other place throughout the planet; they have a very low chance of getting diseases and they happen to be some of happiest people on the planet. This is why Buettner and his team conducted a research to better understand why these places are living much longer than the rest of the world, and what the characteristics are in these places that contributes to the longevity of the community of this specific region.

There are five Blue Zones around the world located in:

1. Ikaira, Greece
2. Okinawa, Japan
3. Sardinia, Italy
4. Loma Linda, California
5. Nicoya Peninsula, Costa Rica

Beuttner and his team understood that the factors that lead to longevity was by large part from the lifestyle and the environment that people lived in. This was justified through the Danish Twin study which proved that the human gene is only a factor of 20 % of the influences to the length of life.[342] Therefore it was in their knowledge that behavioral and environmental characteristics were the primary influence in the longevity of the population in these specific places. Buettner's goal is essentially to determine what these characteristics were.

Power 9

Their findings are explained in his book *The Blue Zone: lessons for living longer from the people who lived the longest,* which determines that there are 9 common behavioral characteristics accumulated from the blue zone places. These characteristics are labeled as the "power 9," which consists of; moving naturally, purpose, downshift, 80% rule, plant slant, wine at 5, belong, loved one first, and right tribe which will be briefly explained as defined by Buettner.

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[342] Dan Buettner. " Power 9: Reverse Engineering Longevity." *The Blue Zones*, 2016. Accessed December 8, 2016.https://www.bluezones.com/2016/11/power-9/

Figure 88: Blue Zone Power 9

1. *Moving naturally*

Moving naturally is as it sounds; the blue zone communities are always active except without much effort. The environment of the blue zones are situated and developed in a way that motivates the community to naturally be physically active such as gardening, doing chores, or walking to the beach.[343]

2. *Purpose*

The blue zone communities have very strong cultural values which help them to be healthy and happy, and one of the most impactful practices that they have is the belief of belonging or their sense of purpose. The Okinawans for example have a saying; "ikigai," or the Nicoyans who

[343] Ibid.

would say, "plan de vida" which both translates to "why they wake up in the morning."[344]

3. *Down Shift*

The blue zone communities really appreciate the value of relieving their stress, which is very influential to the physical health. What the centenarians do to relieve stress is on Okinawa, they would some time daily to think about their ancestors, the Adventists would pray, the Ikarians would take a nap each day and the Sardinians would go for a beer at a local bar.[345]

4. *80% rule*

Pertains to the concept of not eating too much instead to eat until the stomach is about 80% full. The Okinawans have a very old belief in which they would say "Hara hachi bu" that would remind them not eat until completely full.[346]

5. *Plant Slant*

Food with high omega 3 acid such as beans, soy , lentils, nuts, including vegetables is usually the common diet for the blue zone people. Meat on the other hand is rarely eaten (about 5 times a month).[347]

6. *Wine at 5*

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[344] Ibid.
[345] Dan Buettner. " Power 9"
[346] Ibid.
[347] Ibid.

Most of the blue zone population except the Adventist would usually socially drink a minimal amount of alcohol, about a glass or two with food and the company of friends.[348]

7. *Belong*

Most of the blue zone people had a strong religious belief, they would attend religious services on a time that they could.[349]

8. *Loved One First*

The blue zone communities are very family centric, families would make sure that the oldest member of the family is taken care of and either live with or nearby the homes.[350]

9. *Right Tribe*

The blue zone people surrounded themselves with friends that whom support their healthy lifestyle, which is an additional factor to their longevity. The Okinawans for example had “moais” which is a group of five people whom remained friends for a lifetime.[351]

16.2 Interrelation

Based on Buettner’s definition, there are common characteristics from the blue zone communities that can be directly translated into physical spaces, which include *moving naturally, finding a purpose, having*

[348] Ibid.
[349] Ibid.
[350] Dan Buettner. " Power 9”
[351] Ibid.

downshifts, focus on loved one first, and *being in the right tribe*. The intent of this observation is to determine whether the architectural design criteria have the appropriate attributes that will create a physical environment similar to the environments of the blue zone communities which promote healthy behaviors, and potentially improve the life-span of the occupants. In the next section, the blue zone characteristics particularly those that are translatable into physical spaces will be paralleled with the proposed design principles to determine its health qualities.

Bioclimatic Design

As defined previously, bioclimatic architecture is a design principle that focuses on the climate responsiveness of the building to provide a comfortable indoor environment. In relation to the blue zone characteristics, *bioclimatic* design correlates directly with the qualities of *moving naturally*. As defined by Buettner explained previously, moving naturally relates to the environment itself and the qualities it consists of that motivates people to intuitively move. When looking at the climate of these various blue zone locations they all have something in common and that is they are all situated in regions that have very desirable climate either sub-tropical, tropical, or Mediterranean. This makes it clear to why the communities in the blue zones have no issue as far as making a decision to be active. In essence, bioclimatic design inherits this quality because of its single objective to creating a comfortable environment. In the book *Human Thermal*

Environments: The effects of Hot, Moderate, and cold The thermal comfort of the Environments on Human Health, Comfort and Performance, Ken Parson suggests that the thermal comfort of an environment impacts the overall productivity of a person to do work primarily because of the influence that temperature have to the psychological and physical condition of a person, and consequentially affects the activity and productivity.[352] In support of this argument, Parson also mentioned that in a moderately warm climate the attentiveness of a person improves from the ease of stress.[353]

In addition to the improvement of the environmental comfort, bioclimatic design utilizes energy efficient systems, in this case the passive systems that promotes adaptive comfort that requires manual operation supplements the idea of moving naturally. Parson adds that the adaptive comfort design can further enhance the quality of the performance of a person's work.[354] Upon analyzing the topography of the various blue zone regions, there is a common characteristic of the environment that most of these places have and that is that the topography of being hilly or mountainous. With a hilly topography and a healthy lifestyle that prefers to walk or bike, it is clear to why the blue zone population are living longer. In a similar concept, the building circulation system, skip stop elevator, also

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[352] Ken Parsons. *Human thermal environments: the effects of hot, moderate, and cold environments on human health, comfort, and performance*. (Crc Press, 2014). 388.
[353] Ibid, 394.
[354] Ibid

encourages moving naturally, the elevator stops only at every three floors to reduce energy consumption but beyond that promotes healthy lifestyle by encouraging the occupants to use the stairs naturally. These are building attributes that bioclimatic design embraces; therefore it is obvious that the bioclimatic design criteria promote the characteristics of moving naturally.

Adaptive Design

When looking back at the blue zone communities, they have specific cultural values that they embrace truly which is very significant to their well-being, and that is putting their *family first* and surrounding themselves with the *right people*. As described in the previous section, the blue zone places have certain attributes that translate these values. In Sardinia for example as portrayed in his book *Blue Zones: Lessons for Living Longer From People Who Lived the Longest*, Dan Beuttner would discover that family was the center of it all, in one of his interviews he would ask a person why he was still caring for his weak mother? His response was that "it would be a dishonor to the family to even think of a thing like that."[355] Similar value is observed in Nicoya where a village consisting of one large family, would regularly gather with the oldest member of the family for any sort of event, and also the grand children would visit daily to play games for example.[356] The value in their family resonated throughout the communities of the blue zone, and it was

[355] Buettner. "Blue Zones.," 255.
[356] Ibid.

displayed through constant interaction and care. What stands out the most is that the children in most of the blue zone places would welcome the older generation into their home.[357] This demonstrates is a clear relation to the adaptive design criteria, which is a proponent of the multigenerational household that is prominent in Hawaiʻi. As discussed earlier, the families in Hawaiʻi have a strong affection for each other, which is displayed by the "*na ohana*" belief. This is supported through the multigenerational household which is often translated to the Additional Dwelling Unit or the Ohana Dwelling characterized by its adaptability. Through this concept, the characteristic qualities of the adaptive housing to promote intergenerational households are embraced in the adaptive design principle, allowing families to have extended members reside with them, therefore in relation to the blue zone elements, the adaptive design resembles a characteristic similar to the blue zone regions of putting family first.

Moreover, the adaptive principle promotes also the idea of *being in the right tribe*. Observed by Buettner, the Okinawan's have a practice have called "Moai," which is a group of friends who would gather together, usually at someone's house in a common space where they would socialize about almost anything. The same could be said about the Sardinian centenarians who would end their day at a bar with some friends. This was helpful to their health and longevity because it allowed them to be with lifelong friends who

[357] Ibid.

would emotionally uplift each other through conversations and laughter.[358] Referenced in the book, a research done by Professor Lisa Berman in Harvard University on "social connectedness and longevity," shows that people who had more social relations were living longer than compared to the opposition.[359] In relation to the design criteria proposed in this research, adaptive design principles provide spaces that are flexible which creates an opportunity for families to have gathering spaces. In a similar manner, the intergenerational scheme of the building design permits social inclusiveness through design elements such as the vertical courts and other community or shared spaces.

Biophilic Design

Some common characteristics of the blue zone regions is the type of environment that they live in. As already mentioned, the geography of these places are very hilly and mountainous for the most part, but also surrounded with the natural environment. Four of the five blue zones are located on islands that fairly underdeveloped, surrounded by vegetation, ocean and natural landscapes along with temperate climates in which they fully take advantage of. Being surrounded in this environment persuades them to naturally want to move as described previously which is beneficial to the physical health. Looking at the activities that blue zone centenarians do

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[358] Buettner. "The Blue Zone," 258.
[359] Ibid.

regularly, they are often in the outdoor environment such as shepherds walking the sheep, winemakers caring for their grapes, or sphere fishing at the sea.[360] The other part to this is the psychological impact of being surrounded by the natural environments, which attains restorative values that helps to reduce and prevent stress, which are characteristics relating to having *downshifts*.[361] Another way to achieve this is through gardening, most of the Okinawan centenarians have or had a garden in which they were very active in. Gardening to the Okinawans was something that they worked on daily. It kept them active, provided them with fresh vegetables to eat and also reduced their stress.[362] Being exposed to the sun is another factor that is good for their health, aside from providing their bodies the vitamin D, it also has qualities that reduces psychological pressure.[363] Beyond providing downshift for the centenarians, the symbiotic relation between human and nature that reduces stress and creates an uplift in spirit or happiness, becomes a motivation for the centenarians to live, which is an aspect of the blue zone element of *finding a purpose*.

As discussed in previous sections biophilic design has a direct relation with the bioclimatic principles, which ties directly to the concept of integrating the natural environment in the architecture design. When

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360 Buettner. “The Blue Zone”

361 Stephen Kaplan. "The restorative benefits of nature: Toward an integrative framework." *Journal of environmental psychology* 15, no. 3 (1995): 169-182.

362 Buettner. “The Blue Zone,” 119.

363 Ibid.

comparing with the blue zone characteristics there are similarities, particularly with the implication of vegetation and natural elements such as wind and daylighting as well as natural materials that become attributes of the building. Bioclimatic design embodies the climatic conditions, often applying passive solutions in providing comfort. Therefore the use of natural ventilation and daylighting is highly implemented. In addition, the social spaces with ecological components like the sky lanai become spaces that permits gardening for the occupants who like the Okinawan community becomes a place their downshift and a catalyst for their "*Ikigai*" or the "purpose for waking up."[364]

17. Design

Overview

The following section will propose an architectural prototype that applying the design criterion. The prototype will be an intergenerational residential high-rise for families, individuals and especially for older adults in Urban Honolulu, particularly in the Kaka'ako district of Urban Honolulu.

Location

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[364] Buettner. "The Blue Zone," 87.

Figure 89: Kaka'ako District

Kaka'ako is a commercial and retail district, located in central urban Honolulu. It is currently undergoing a major development overlooked by the Hawaii Community Development Authority (HCDA).[365,366]

[365] *Mauka Area Plan: Kakaako Community Development District*. Report. Hawaii Community Development Authority (HCDA). Honolulu, HI. September 2011. Accessed January 27, 2017. https://dbedt.hawaii.gov/hcda/files/2013/02/Mauka-Area-Plan-EFF-2011-10-31.pdf, 1.

[366] *Kaka'ako Community Development District TOD Overlay Plan: Executive Summary, Draft*. Report. Hawaii Community Development Authority (HCDA). Honolulu, HI. May 2013. Accessed January 27, 2017. http://dbedt.hawaii.gov/hcda/files/2013/05/kakaako-tod-overlay-ex-sum-draft-5-13.pdf, 3.

Figure 90: Transit Oriented Development ¼ mile radius

Figure 91: Mapping Diagram of Rail Station and Street Walkability & Pedestrian Prioritized Streets

As part of the transit oriented development throughout the island, the major plan for Kaka'ako is to improve the livability and sustainability of the community by providing housing options with parks, community spaces, and easier commutes.[367] This is achieved through various design principles including optimizing land use and transportation, improving the quality of the streets through connectivity and applying the Complete Streets Criteria, designing the environment for people, concentrating activities around public transits, mix-use of programs, and encourages sustainable commutes.[368] The development principles for Kaka'ako make the community a desirable environment for families to live, especially for older adults, creating a walkable neighborhood, providing community spaces for people to socialize and interact with nature, and also an environment that promotes sustainable and healthy lifestyle. These characteristics that Kaka'ako will acquire make it the more suitable location for the design proposal of this research.

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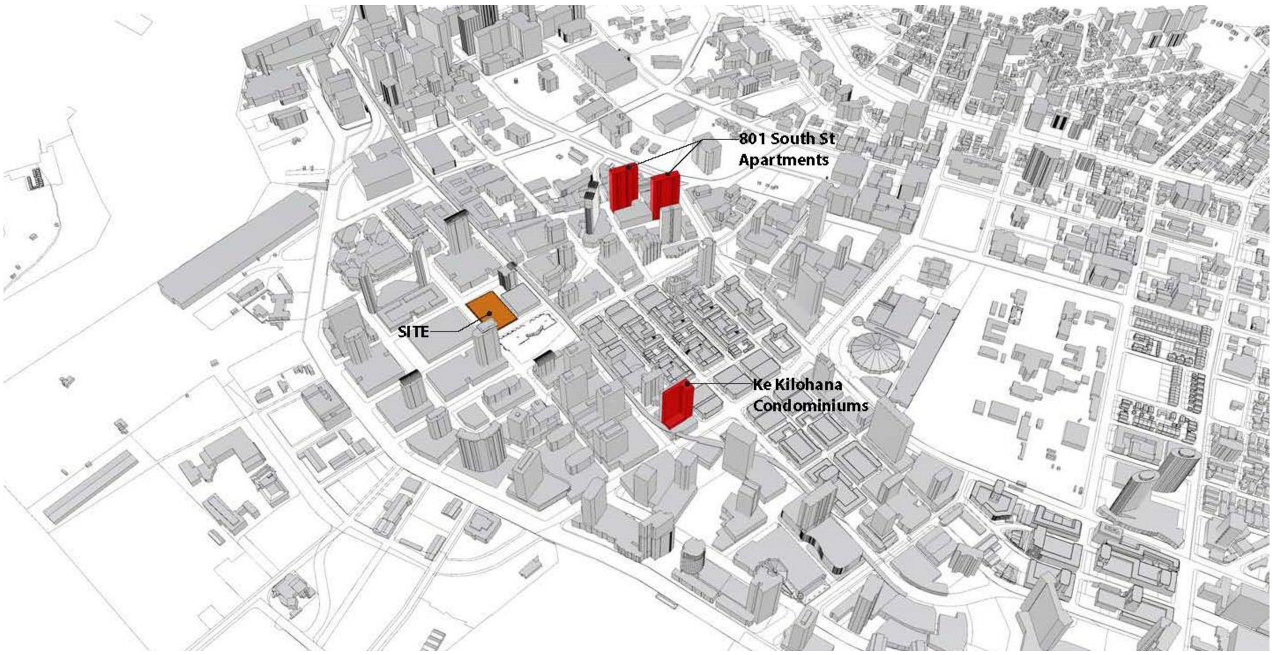
[367] *Mauka Area Plan,* (HCDA), 1.
[368] *Kaka'ako TOD Plan*. (HCDA), 4.

17.1 Design Parameters

Existing



To generate design parameters for the prototype, two residential high-rises will be examined as precedents to determine the general number of units, unit sizes, building height, and programmatic organization. The two buildings are "Halekauwila Place" at 665 Halekauwila st. and "Ke Kilohana" at 988 Halekauwila st.

Figure 92: 801 South Street Apartments High-Rise

Figure 93: 801 South St. Typical Floor Plan

Source: 801 South Street. Accessed February 04, 2017. http://www.801southst.com/.

The "801 South Street Apartments" is considered a workforce housing high-rise with 46 floors and 635 units; 90 studio units, 21 single bedrooms, and a total of 92 two-bedrooms with 1-2 baths.[369] Based from the type of units given, the building offers housing for a diverse group of occupants that could promote an intergenerational community. The residential high-rise also includes amenities including personal laundry rooms within the units,

[369] *801 South Street Development Permit Application.* Hawai'i Community Development Authority. 2012. Accessed February 4, 2017. http://dbedt.hawaii.gov/hcda/files/2013/09/801-South-Permit-Application-9-12-12.pdf.

community bike storage, recreational multipurpose rooms, and outdoor common spaces such as the garden.[370]

801 South St (Affordable Apartments**)** Source: 801 South Street. Accessed February 04, 2017. http://www.801southst.com/.		
Unit Type	**Family Size**	**Typical Unit Plan**
<u>Studio</u> (only building A) 90 units 407 sf		
<u>1 bedroom</u> 21 units 495-522 sf		

[370] "Features." 801 South Street. March 29, 2016. Accessed February 04, 2017. http://www.801southst.com/features/.

<u>2</u> **<u>bedrooms</u>** 1 &1.5 bath 71 units 714 sf		
<u>2</u> **<u>bedrooms</u>** **<u>2 bath</u>** 183 units 816 sf		
<u>3</u> **<u>bedrooms</u>** (only building B) 45 units 1,331 sf		

Figure 94: Ke Kilohana Condominium High-Rise

Figure 95: Ke Kilohana Typical Floor Plan

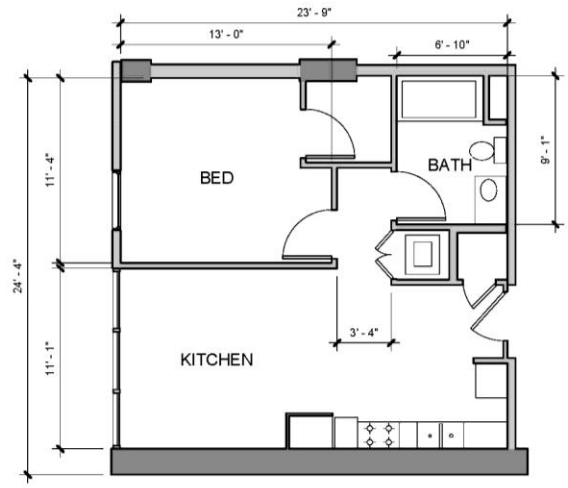
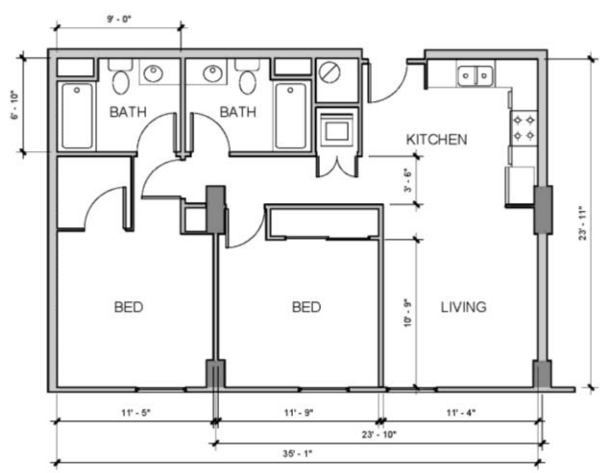
“Ke Kilohana” is a mixed-use condominium high-rise, which offers “reserved” (low or moderate income) housing units.[371] The building consists of 43 floors with 424 mixed-use units which includes 141 single bedroom, 193 two bedrooms, and 90 three bedrooms.[372] The building also has various amenities included, such as community storage, multipurpose studio spaces,

[371] *Kaka'ako Reserved Housing Rule*. CH. 218. Hawai'i Community Development Authority.. Accessed February 3, 2017. https://dbedt.hawaii.gov/hcda/files/2013/02/Ch.-218-Kakaako-Reserved-Housing-Rules-EFF-2011-11-11.pdf. 218-5.

[372] Development Permit Submission To The Hawaii Community Development Authority For Ward Village, Land Block 5, Project 1 404 Ward Avenue. Hawaii Community Development Authority. 2013. Accessed February 3, 2017. http://dbedt.hawaii.gov/hcda/files/2013/06/HCDA-Application-130605.pdf. 3.

performance stages, working spaces, multipurpose lounges, playgrounds, kids playroom, sky decks, and fitness rooms.[373]

<table>
<tr><td colspan="3">Ke Kilohana (Reserved Housing)

Source: Ward Village - Block 'O' - Reserved Housing Tower Drawings. Hawai'i Community Development Authority. Accessed February 4, 2017. http://dbedt.hawaii.gov/hcda/files/2013/06/HCDA-Application-130605-Drawings-11x17.pdf. Redrawn by author.</td></tr>
<tr><th>Unit Type</th><th>Family Size</th><th>Typical Unit Plan (not to scale)</th></tr>
<tr><td><u>1 bedroom</u>
141 units
461-511 sf</td><td></td><td>
</td></tr>
<tr><td><u>2 bedrooms</u>
193 units
728-800 sf</td><td>
</td><td>
</td></tr>
</table>

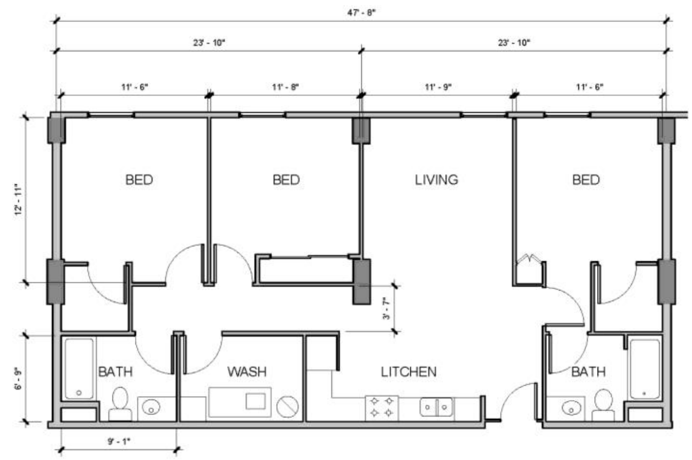
[373] Howard Hughes Corp. *Ke Kilohana Residences* . Accessed February 3, 2017. http://broker.wardvillage.com/cms_uploads/docs/ke-kilohana_floor-plans.pdf.

3

bedrooms

90 units

977-1,173 sf



Precedent Matrix Analysis

Precedent	Bioclimatic							
	Project Data/ Site Analysis	Form Giver	Transitional Space	Envelope	climate control system			
					high performance glazing	shading	natural ventilation	hybrid system
801 South St	na	na	na	na	Double pane glass windows and doors,	Lanai, Blinds	Operable windows, Lanai spaces	Split air condition system
Ke kilohana	Wind analysis	na	Sky courts	na	na	Blinds	Sky courts	na

Precedent	Adaptive			Biophilic			
	Building level	Unit level	Room level	Environmental factor	Natural Shapes	Light	Space
801 South St	na	na	lanai space	Orientation to preserve view access, 100% of tower parallel to South st façade, site Landscape, Street trees	na	Daylighting	Diversity of space volume and size
Ke kilohana	na	Light framed partitions	Light framed partitions	Orientation to preserve view access, parallel to Ward avenue 38 degrees west of south, Sky courts, Landscape view, Street trees	na	Daylighting	Diversity of space volume and size

Overview

After the brief assessment of the two residential high-rises in *Kaka'ako* some of the commonalities discovered include building footprint form and dimension, building height, unit size, circulation and structural configuration.

Footprint Form and Dimension

- Narrow rectangular footprint
- Dimension approximately 55' depth X 200'

Building Height

- 400'

Unit Size

- 1 bedroom; 460-640 sf
- 2 bedrooms: 730-800 sf
- 3 bedrooms: 1,000-1,300 sf

Room Size

- Bedrooms: ranging from 120-150 sf
- Bathrooms: approximately 65 sf
- Combined Living, Dining and Kitchen: ranging from 250-300 sf

Circulation

- Double loaded corridor
- Circulation core along central perimeter

Buyer's Preference HI		Renters Preference HI	
Single Family	68%	Single Family	43%
Apt/Condo	6%	Apt/Condo	47%
2 Bed Unit	40%	2 Bed Unit	43%
3Bed	29%	3Bed	31%

Size Preference or No Concerns		Size Preference or No Concerns	
800-1,200	46%	800-1,200	41%
1,200-1,500	16%	1,200-1,500	39%

In relations to the design principles, there are characteristics that the two residential blocks acquire, similar to the design criteria. These characteristics relate to the bioclimatic and biophilic principles.

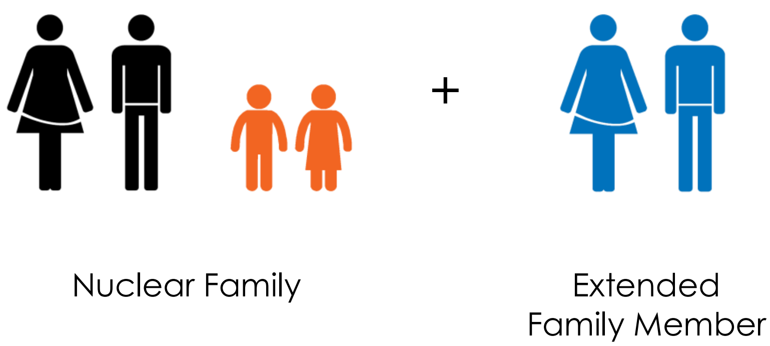
Bioclimatic strategies

- Shading devices
- Natural ventilation strategies

Biophilic strategies

- Orientation based on preserving visual corridors from mountain to the ocean.
- Site landscape
- Street trees
- Daylighting

Some disadvantages however relates to the lack of bioclimatic, biophilic, and adaptive strategies. At the bioclimatic aspect, there are limited strategies applied; building formation in relation to the solar path, shading devices on façade, optimizing natural ventilation, and application of hybrid systems. In relation to the biophilic design concept, there is a lack in the use of daylight, natural materials, organic shapes and lines, and the use incorporation of vegetation in the building. Finally, the most lacking quality is the adaptive concept, the ability for the units to adapt to demographic changes particularly for a multigenerational family is absent. The dwellings built in the residential high-rises includes units ranging from studios and 1 to 3 bedrooms, which has the ability to house residents such as single occupants, couples, couples with a single child, and nuclear families (couple and two child). These units promote an intergenerational community however; the lack of flexibility for the units to house multigenerational families (couple with children and an extended family member(s)) is not suited.



Programming

In reference to the assessment of the two existing high-rise, the objective is to design a high-rise residential that consist of housing for multigenerational families that allows flexibility to adapt to changes in demographic. The design of this prototype will explore various possible layouts that are capable of adapting to evolving family sizes including a single occupant, a couple, a couple with a child, a nuclear family, and a multigenerational family.

17.2 Prototype Design

Site Analysis

Figure 96: Site Location and Existing Conditions

The site is on a vacant lot located along the intersection of *Keawe* St. and *Pohukaina* St. The site is approximately 94,423 sf, and situated directly next to an existing park on the south-east and a recently constructed 200ft residential building on the north-east (Figure 96). In addition, as part of the overall *Kaka'ako* master plan (Figure 97) there are buildings in the neighboring blocks that are newly built, under construction, and are being planned, all of which have potential influence to the building design. The impact of these existing buildings to the proposed site is assessed in the following section.

Figure 97: Site Location in Kaka'ako Master Plan

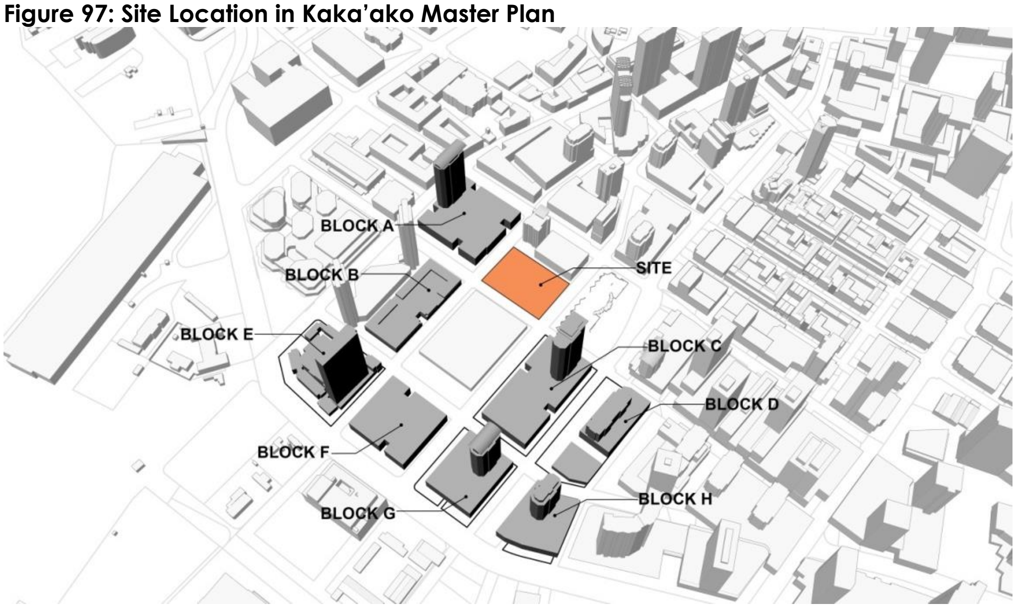
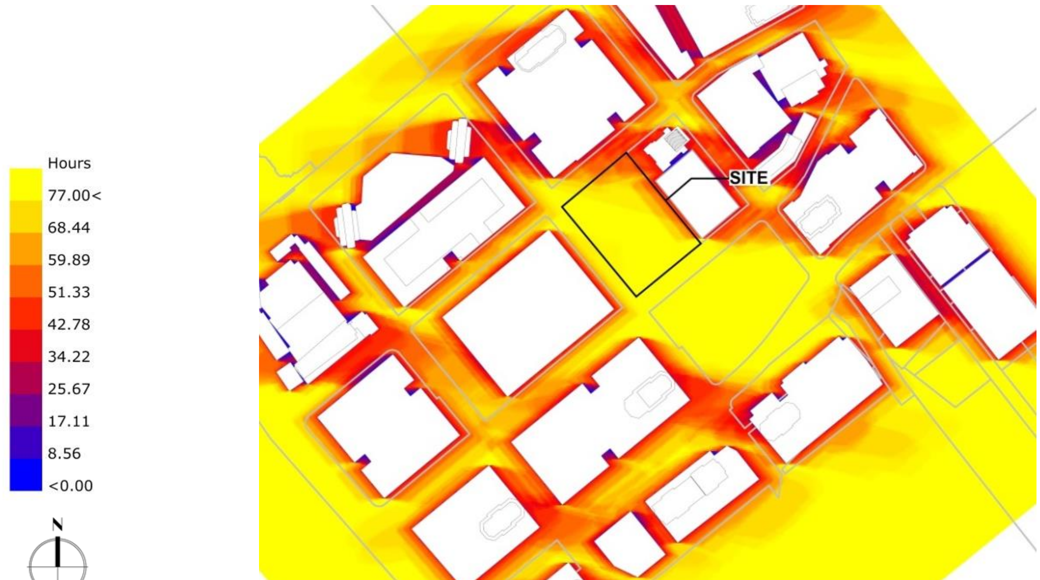
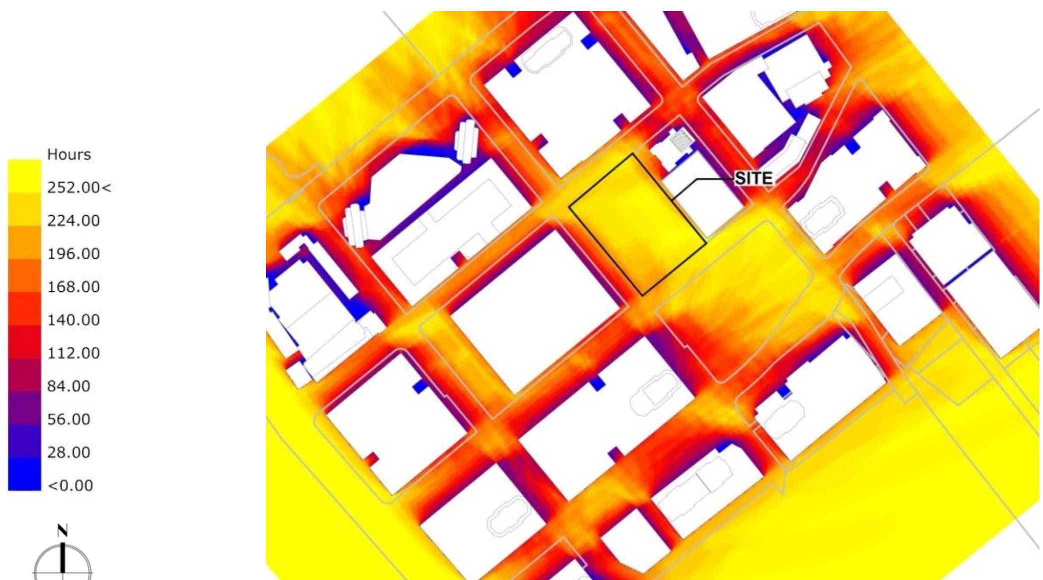


Figure 98: Existing and Proposed Buildings Near Site

Site Climatic Analysis



Daylight Range, May-August, 7 days, 9 am- 5pm



Daylight Range, October - January, 7 days, 9am-5pm

Figure 99: Daylight Simulation on Site

Using computer simulation software, the climate condition on the site including solar and wind, are analyzed. Based on the daylight range during the summer (May – Aug.) and winter (Oct.-Jan.) months, for seven days between 9 am to 5 pm, the site receives a large amount of daylight hours and very little impact from shadows casted on neighboring building

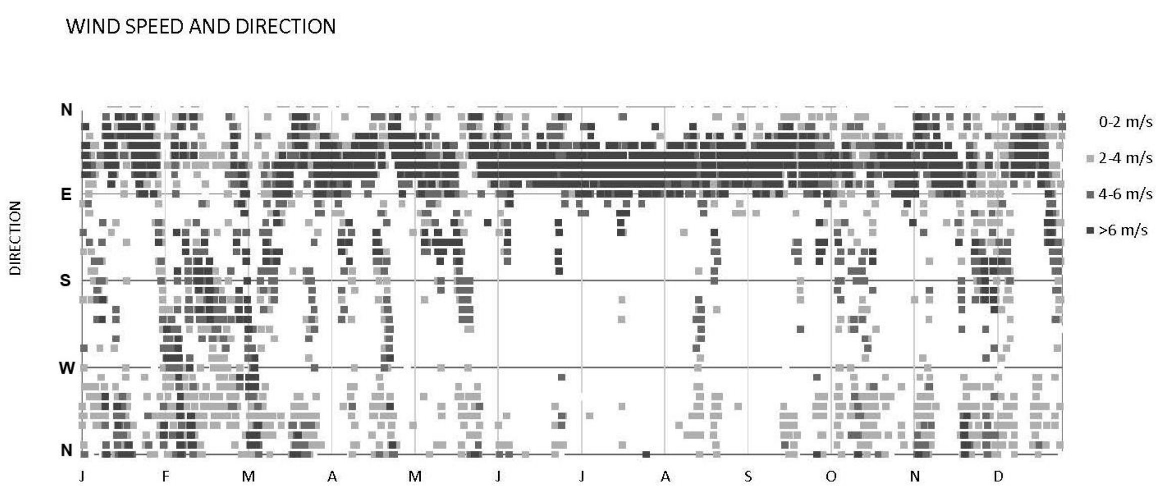
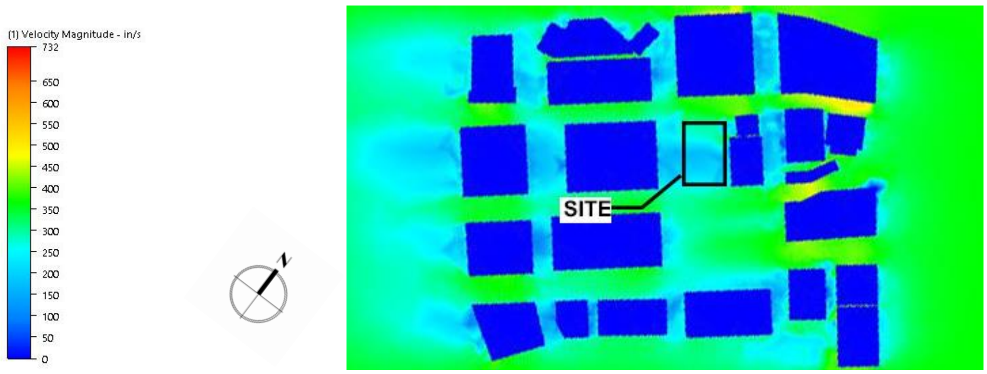
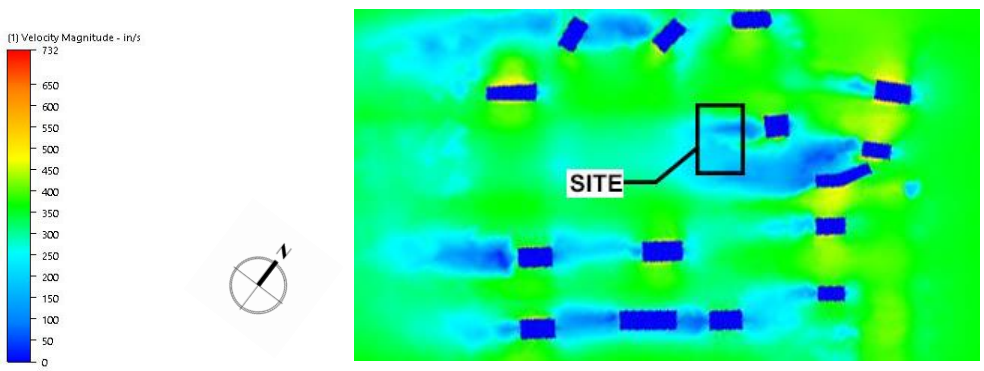


Figure 100: Predominant Wind Direction and Speed for Honolulu, HI

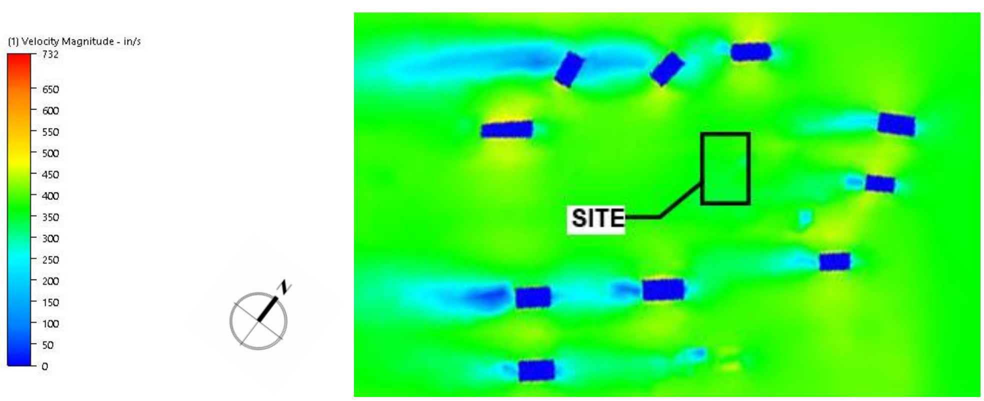
As mentioned previously, Hawai'i's predominant wind direction flows from the north-east and through computational fluid dynamic simulation; the influences of the neighboring buildings can be analyzed.



Wind Flow at 30ft



Wind Flow at 60ft



Wind Flow at 200ft

Figure 101: Site Wind Flow at 30ft, 60ft & 200ft

The result of the wind simulation determines that the site is exposed to high velocity wind, ranging from 300 in/s - 400 in/s (17-23mph)(& **Error! Reference source not found.**). However the existing building on the north-east have an impact on the amount of wind that flows over the site; the existing structures function as a buffer for the high velocity winds particularly on the areas closer to ground level, a significant factor to consider when designing the high-rise.

On the proposed site there are rules and regulations that are enforced by the Honolulu Community Development Authority (HCDA), which impacts the form and performance of the building. The design section will develop two prototypes; prototype one, which takes into accounts the rules and regulation similar to the current buildings that are being constructed in the neighborhood. The second prototype will focuses primarily on the optimization of the building for performance.

17.3 Prototype 1

Prototype 1 will reference similar characteristics as the typical high-rise typology, that are commonly constructed in Kaka'ako, which is the long rectangular shaped building consisting of a double-loaded corridor and a central core. The goal however is to aim for optimizing the performance of this building typology for the occupants using the design criteria as proposed in this research.

Rules and Regulation Determinant

The major regulations and zoning that is enforce on the site include maximum height zone, site lot to building footprint ratio, and the view corridor building orientation.

Figure 102: Building Height Zone, Hawaii Community Development Authority

Table 2: Lot Size to Building Floor Plate Ratio, Hawaii Community Development Authority

Lot Size (Actual Development Lot)	Floor Plate
< 40,000 SF	8,000 SF
40,000 SF – 80,000 SF	10,000 SF – 12,000 SF
80,000 SF – 120,000 SF	10,000 SF – 12,000 SF
120,000 SF - 160,000 SF	12,000 SF – 16,000 SF

> 160,000 SF	16,000 SF

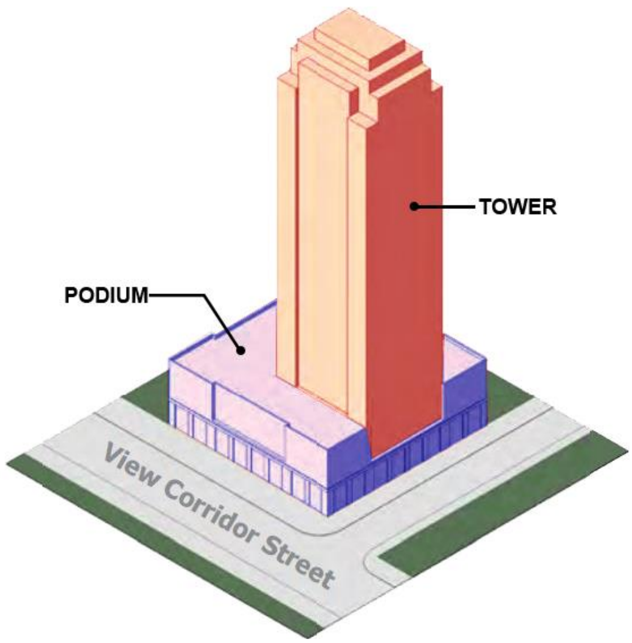


Figure 103: Podium High-Rise Building Typology

Figure 104: Designated View Corridors

The building height zone of the proposed site will be a maximum 400 ft. as administered by HCDA (Figure 102). Since the total site area is 94,423 SF, the maximum floor plate for the high-rise building must be between 10,000 SF – 12,000 SF (Table 2: Lot Size to Building Floor Plate Ratio, Hawaii Community Development Authority). In addition, the building form for any structure above 100 ft. must be a podium high-rise typology (Figure 103). Lastly, 65% of the largest building façade must be oriented parallel to the closest "view corridor" (Figure 105).

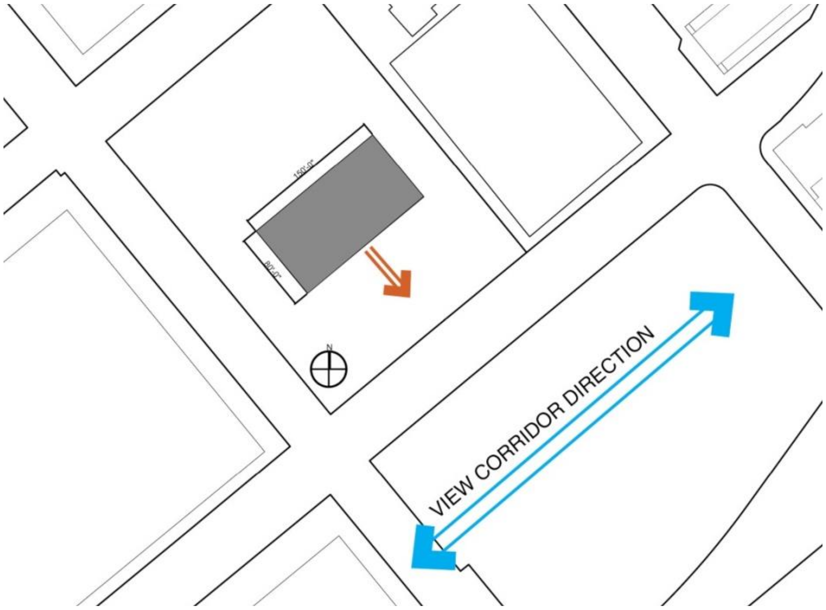
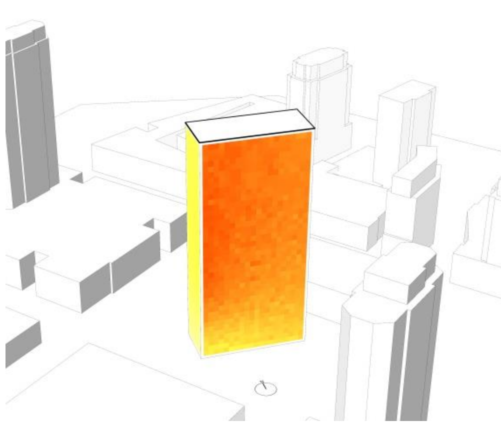


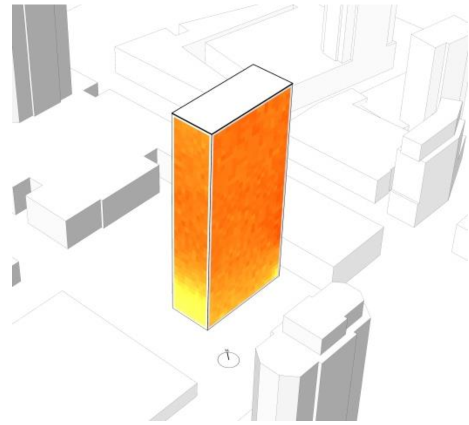
Figure 105: View Corridor Orientation

Following the regulations and building requirements, a general building mass is created; the footprint is 12,000 sf, 400 ft high and oriented parallel to the view corridor. In order to understand the impacts of the climate onto the building, solar radiation and wind flow around the mass will be assessed through computer simulation, and will be compared to a south oriented building mass to better understand the influence of the building orientation.

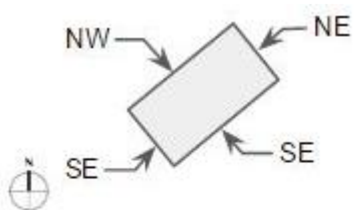
Massing



Mass 1. South Oriented Mass

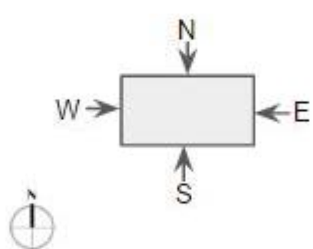


Mass 2. View Corridor Oriented Mass



Mass 1. View Corridor Orientation

	NW Facade	SW Facade	SE Facade	NE Facade
Annual	**447.44** kWh/m2	**779.24** kWh/m2	**842.85** kWh/m2	**548.59** kWh/m2



Mass 2. South Orientation

	N Facade	W Facade	S Facade	E Facade
Annual	**393.26** kWh/m2	**654.85** kWh/m2	**824.49** kWh/m2	**722.91** kWh/m2

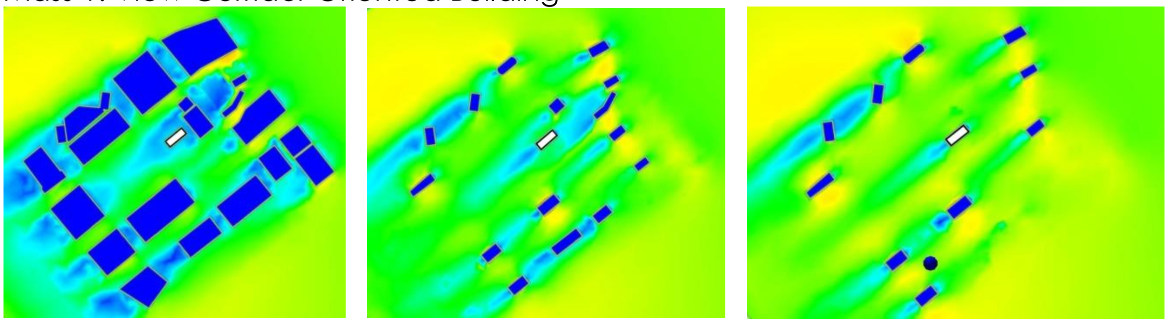
-Highlighted area marks larger facades

Figure 106: Comparison of Solar Exposure for View Corridor and South Oriented Mass

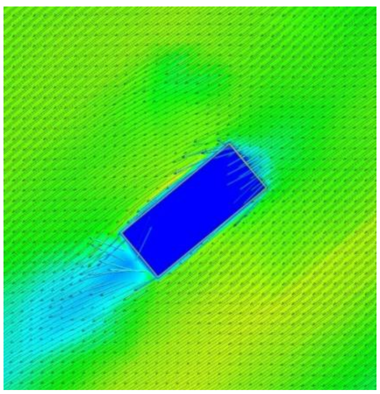
Through a grid-based simulation, the annual surface solar radiation exposure was measured, the results show that the overall exposure for both the corridor-oriented (mass 1) and south oriented (mass 2) building are receiving fairly similar amount of sunlight. However when isolating the larger facades; north-west and south-east for mass 1 and north and south façade for mass 2, mass 1 displays higher amount of exposure overall. This makes sense since the orientation of mass 1, exposes the north-west façade to the low angle afternoon sun. Therefore, when proceeding with the view corridor oriented mass, it is essential to take into consideration the solar impacts on the building surfaces especially for the morning and afternoon hours.

When designing for cooling in Hawaii, natural ventilation is the most efficient and effective solution, and in order to achieve this it is critical to understand the wind flow on the site and how it reacts to the shape and form of the building mass. In the following section, computational fluid dynamics (CFD) simulation was conducted to assess the wind flow around mass 1 at 30ft, 60t and 200ft, this is compared to mass 2 to determine the influence of orientation with wind flow.

Mass 1: View Corridor Oriented Building



30ft 60ft 200ft



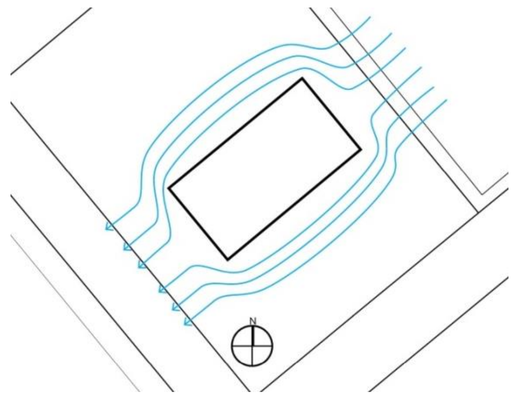
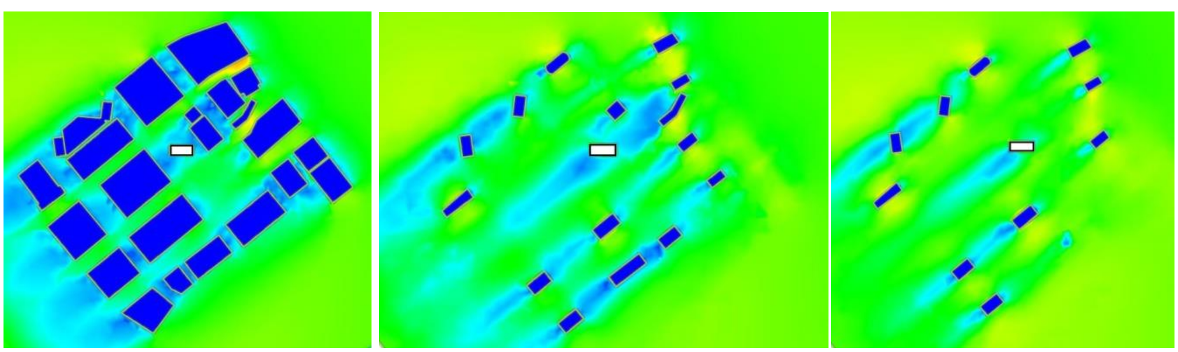


Figure 107: View Corridor Building Mass External Wind Flow Simulation at 30ft, 60ft, and 200ft

Mass 2: South Oriented Building



30ft 60ft 200ft

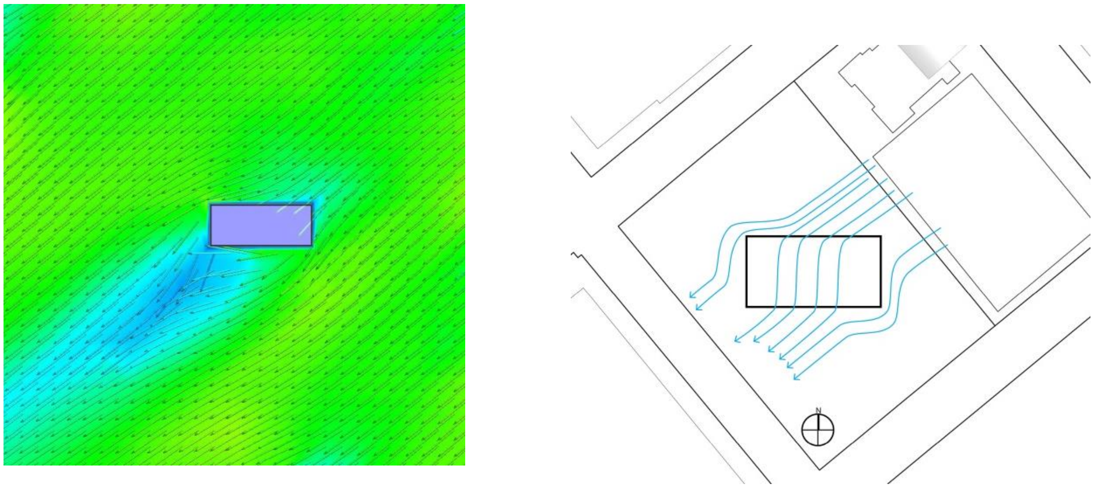
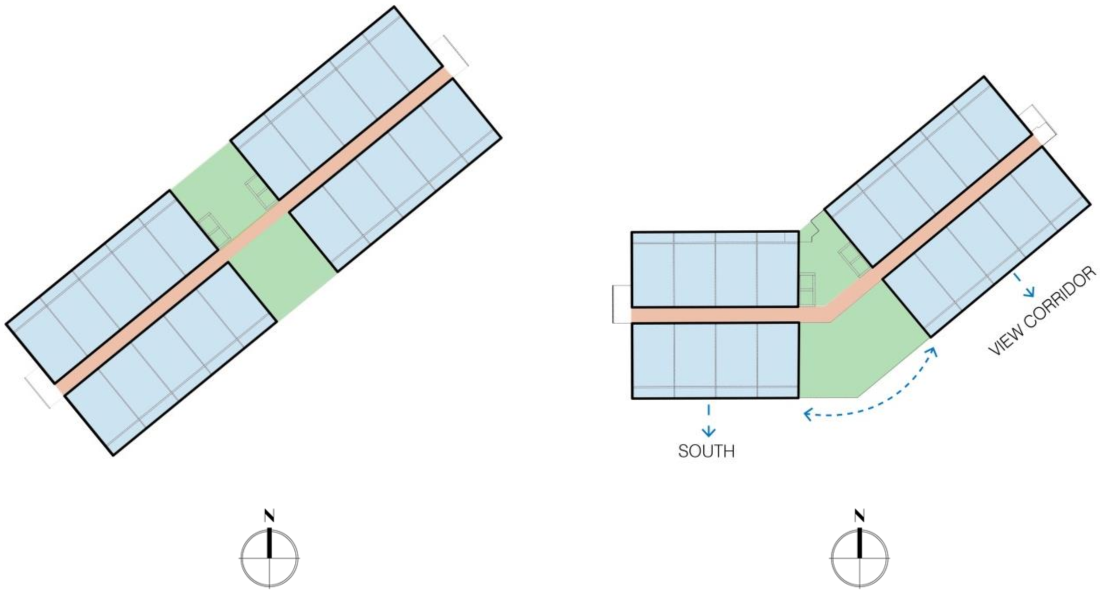
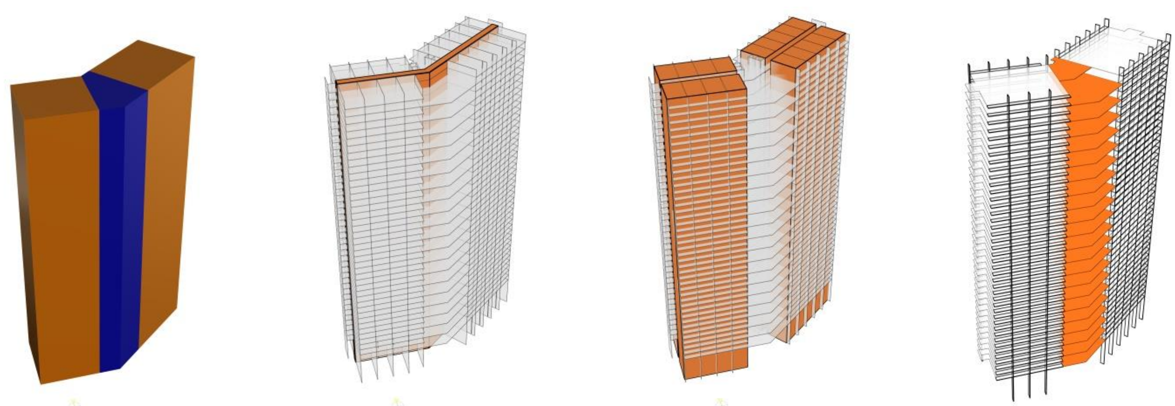


Figure 108: South Oriented Building Mass External Wind flow at 30ft, 60ft & 200ft

When looking at the results, it appears that the wind flow around mass 1 is at a higher velocity than mass 2. The orientation of the building show significant impact on how wind travels around the mass. Since mass 1 (Figure 107) is oriented parallel to the predominant wind direction, the wind flows easily around the building with little resistance than in comparison to mass 2 (Figure 108) which is partly perpendicular to the wind direction. Further analysis is conducted in the following section.

The results of the solar exposure and the wind flow simulation on the building mass, display challenges that must be considered when designing the building. The solar exposure simulation on mass 1 dictates that all surfaces particularly the larger facades on the building have significant heat gains that needs to be mitigated. In addition, the orientation of the building form brings challenges in providing cross ventilation, an essential element to achieving passive cooling.

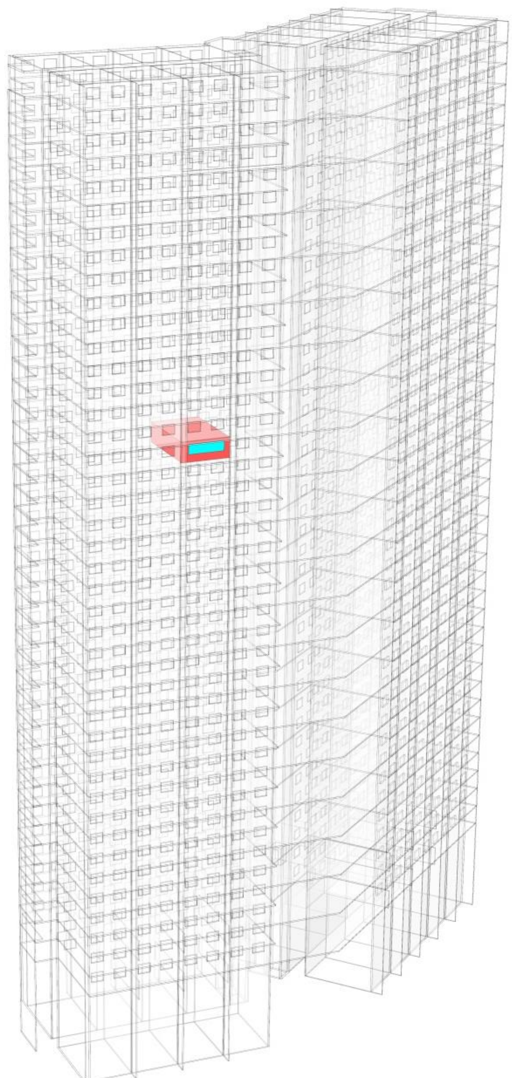


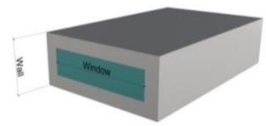


Mass Composition | Double Loaded Corridor | Units | Sky Lanais

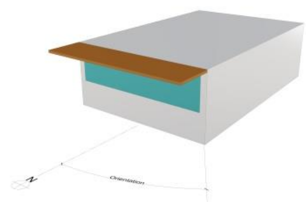
As a result the building form for prototype 1 will consist of a building mass that is oriented primarily parallel to the view corridor, meeting the requirement, but will also have a portion that is oriented south to intercept the wind flow, increasing the opportunity for cross ventilation.

Shading Design

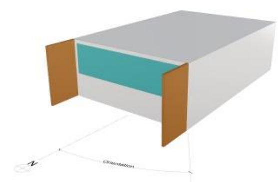




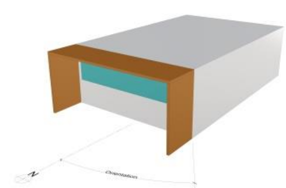
Window to Wall Ratio



Overhang

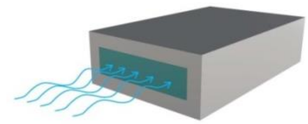


Fins



Combined Shading

Location of Unit for Comfort Simulation



Ventilation Rate

To reduce the direct solar gain, effective shading device must be applied on to the building façade. To determine the most effective shading system, parametric comparison simulation will be conducted to assess the impact of window to wall ratio, three types of shading systems in various depths and in various orientations; overhang, fins and a combined horizontal and vertical shading device (both). In addition, the rate of natural ventilation is also measured to better understand the significance of natural ventilation to achieve comfort. These parametric simulations of the window and shading device characteristics are accomplished with Energy Plus program using Designbuilder software as its interface. The scenarios are measured by thermal comfort within a single unit representing a typical unit for prototype 1 and prototype 2. The unit for prototype 1 is approximately 600 sf (20ftx30ft) of floor area and situated 250 ft. above the ground. Prototypes 2 consist of a 1050 sf (35ftx30ft) unit also situated 250ft above ground. The influence of height difference was not simulated in this study; instead the height of which the unit was placed represents the average condition of the units in the building. Thermal comfort in this case is calculated by the total discomfort hour.

Annual Discomfort Hour Percentage

$$Annual\ Discomfort\ Hours = Total\ discomfort\ hours\ over\ a\ year(3650)$$

Thermal comfort, which was used to calculate the *Annual Discomfort Hours*, is based on the Acceptable Thermal Conditions in Occupant-Controlled Naturally Conditioned Spaces.[374] A comfortable thermal comfort hour occurs when during such hour the indoor operative temperature will be within 80% acceptability limits and therefore, a discomfort hour is when the indoor operative temperature during that hour is located outside of the 80% acceptability limits (Figure 109). The total discomfort hours were only calculated only when occupants were present in the simulated zone or space which is based on a basic schedule from 8am-5pm, including the weekends. In this case, the total occupant presence hours over the course of a year, is 3650 hours.

[374] Standard, A. S. H. R. A. E. "Standard 55-2013—Thermal Environmental Conditions for Human Occupancy." *ASHRAE Inc., Atlanta*, GA (20013). 4.

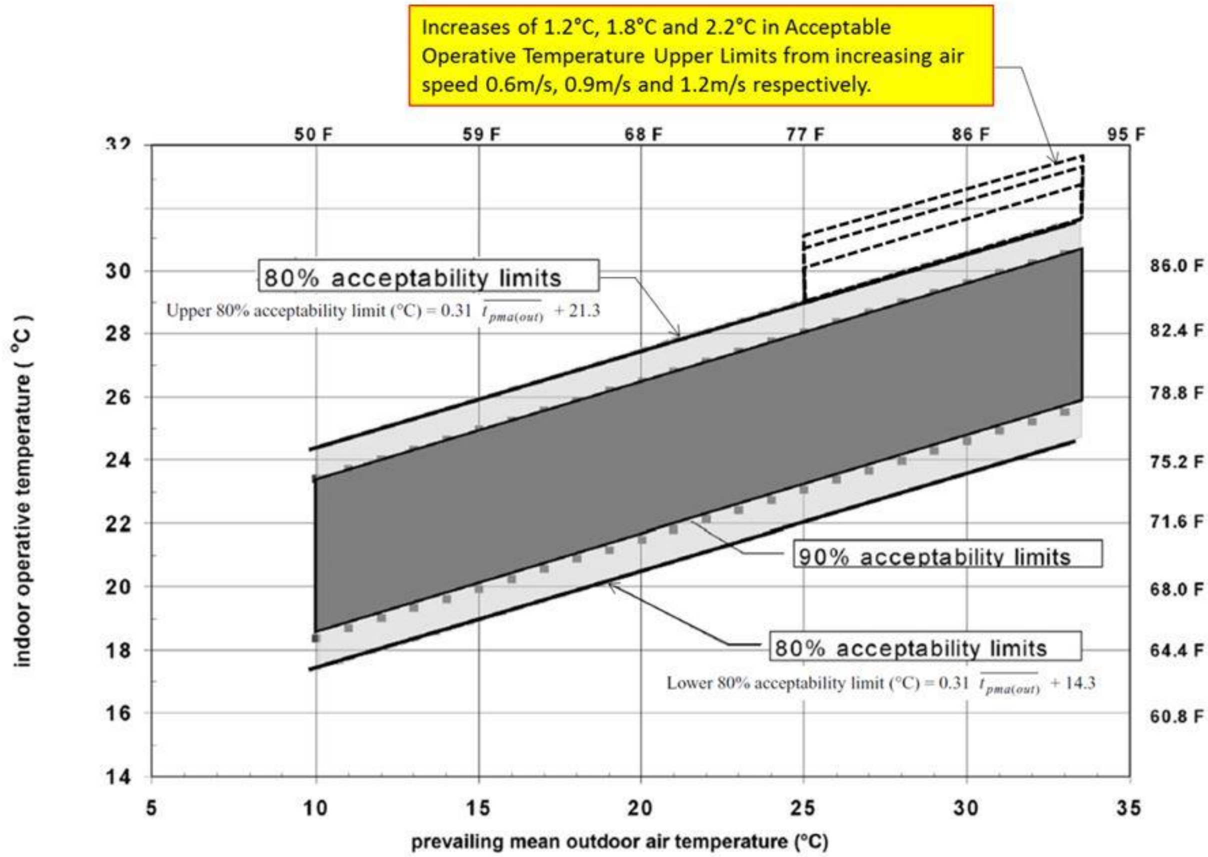


Figure 109: Acceptable operative temperature from naturally conditioned spaces, adding increases of the upper limit resulting from increasing in air speeds. Source: ASHRAE 55-2013.

*$t_{pma(out)}$: the prevailing mean outdoor air temperature is a simple arithmetic mean of all of mean daily outdoor air temperatures of 30 sequential days period to the day in question.

When the operative temperature is greater than 25C (77F), the upper limits are adjusted accordingly to the increasing air speed as follows (Table 3):

Average Air Speed (V_a) 0.6 m/s (118 fpm)	Average Air Speed (V_a) 0.9 m/s (177 fpm)	Average Air Speed (V_a) 1.2 m/s (236 fpm)
1.2°C (2.2°F)	1.8°C (3.2°F)	2.2°C (4.0°F)

Table 3: : Increases in Acceptable Operative Temperature Limits in occupant-controlled, naturally conditioned spaces resulting from increasing air speed above 0.3m/s (59 fpm) Source: ASHRAE 55-2013.

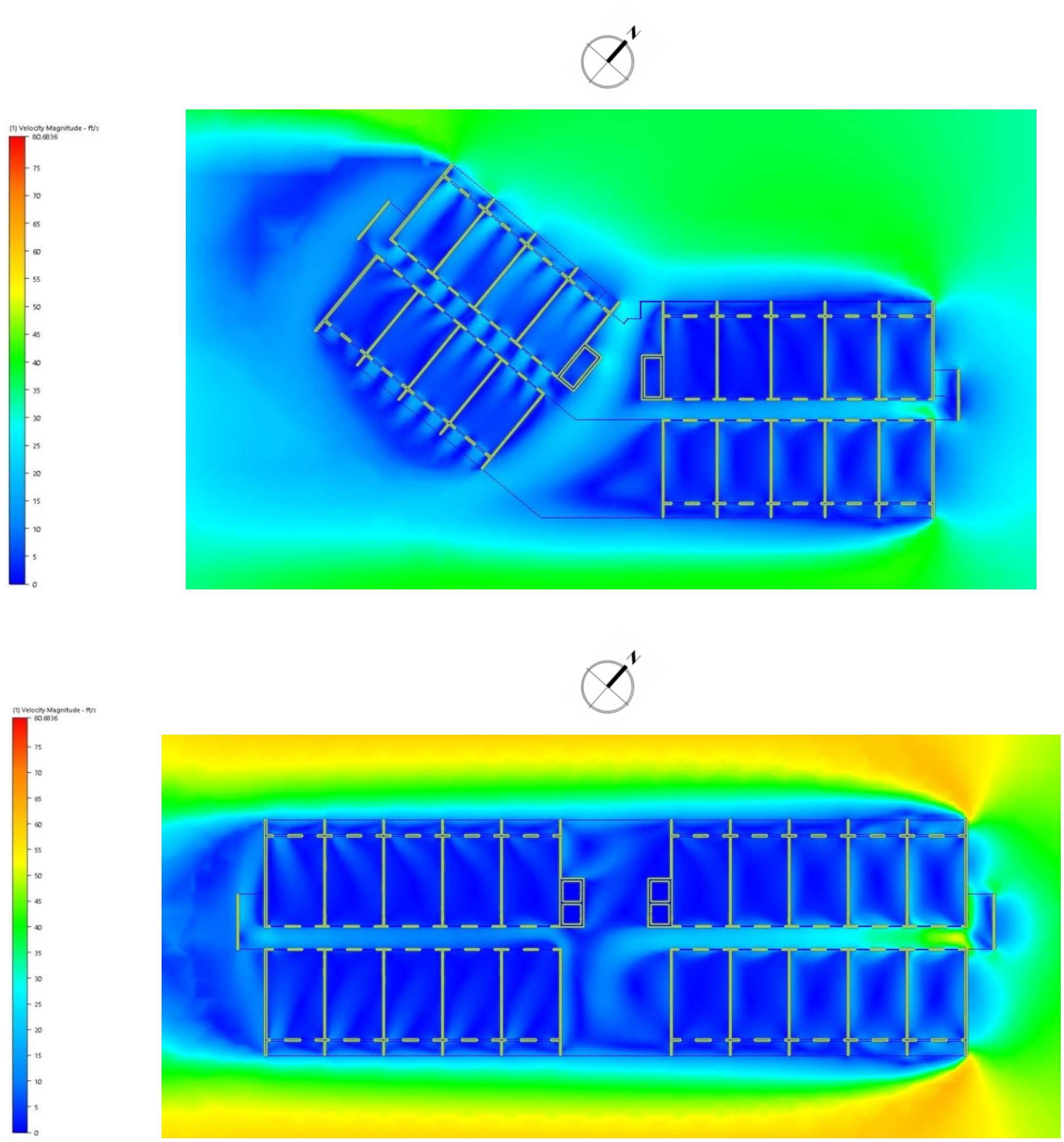
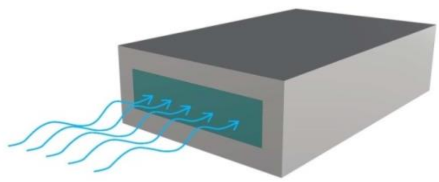
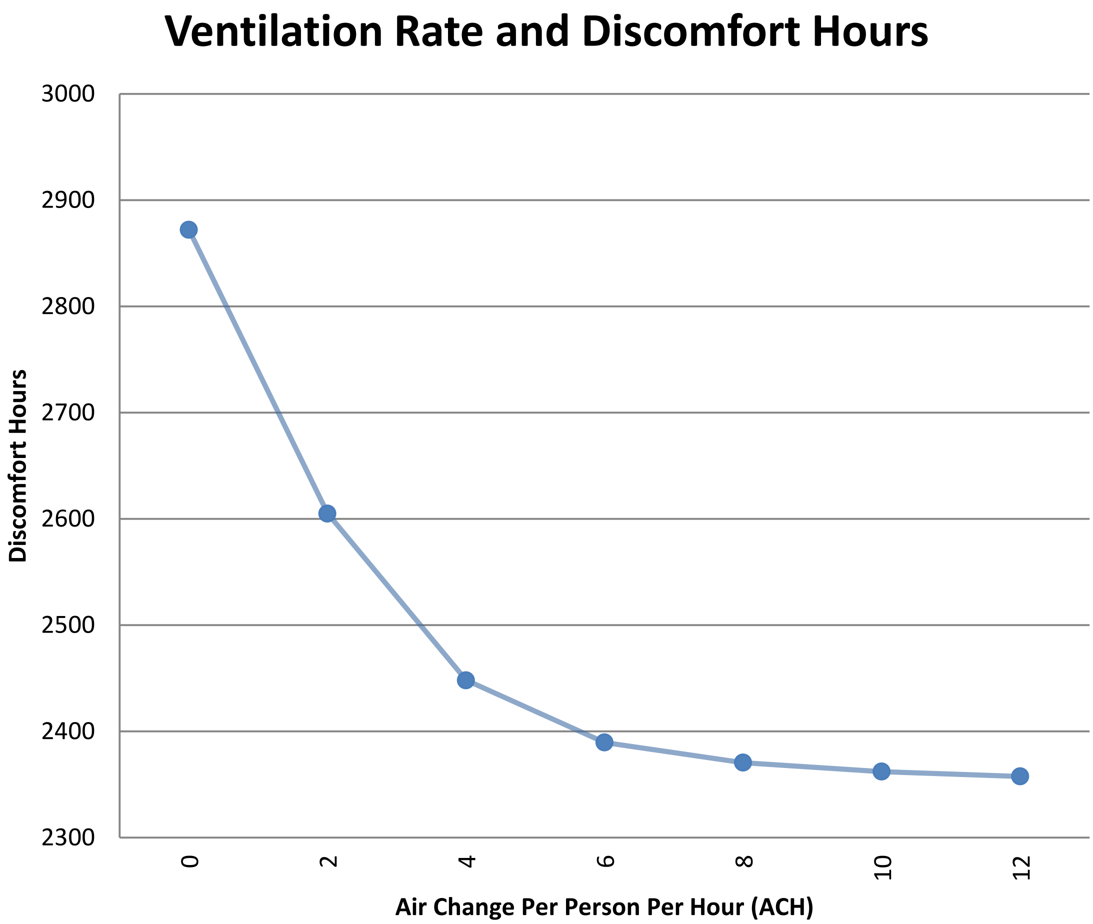


Figure 110: Prototype 1 and simple mass Wind Flow Analysis



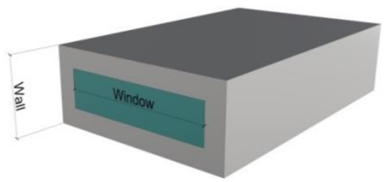


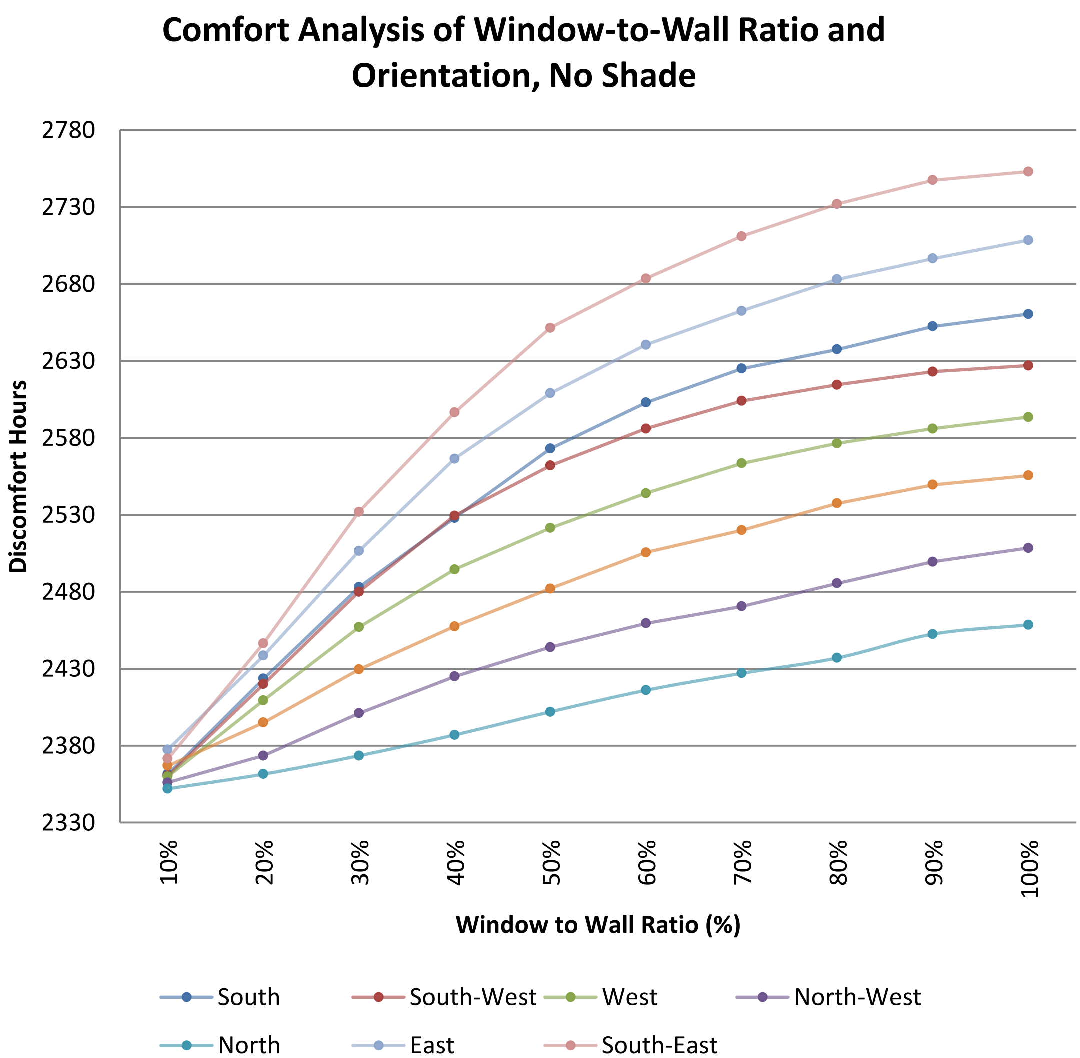
The setup used to simulate the thermal comfort hours in the building consists of fully naturally ventilated residential units. The significance of natural ventilation is essential to providing a comfortable environment.

Therefore designing a building that allows for proper amount of cross ventilation is crucial for cooling especially for Hawaii's climate.

By applying simple openings on the on the exterior façade and on the interior walls along the corridor, natural ventilation was assessed through CFD simulation. The result shows that by reorienting a portion of the building mass, the potential for cross ventilation in the building improves especially for the south-oriented portion. The south-east oriented portion of the building mass displays lack of cross ventilation, however in comparison to the basic rectangular layout, the prototype provides substantial amount of wind flow because of the re-orientation that alters the flow of wind. This is potentially the impact of the building mass almost perpendicular to the predominant wind direction which acts as a buffer to the wind and redirects the flow, also the open space in the center of the building gives passage for a high volume of wind to flow through, which creates pressure that pulls wind from the units facing south-east (Figure 110).

Moreover to justify the importance of natural ventilation for thermal comfort, building simulation was conducted on the ventilation rate by zone or air change per person per hour. The results determine that higher wind flow provides a more comfortable indoor environment, which proves the effectiveness of passive cooling in Hawaii.


Wall
Window


Comfort Analysis of Window-to-Wall Ratio and Orientation, No Shade
2780
2730
2680
2630
2580
2530
2480
2430
2380
2330
Discomfort Hours
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Window to Wall Ratio (%)
South
South-West
West
North-West
North
East
South-East

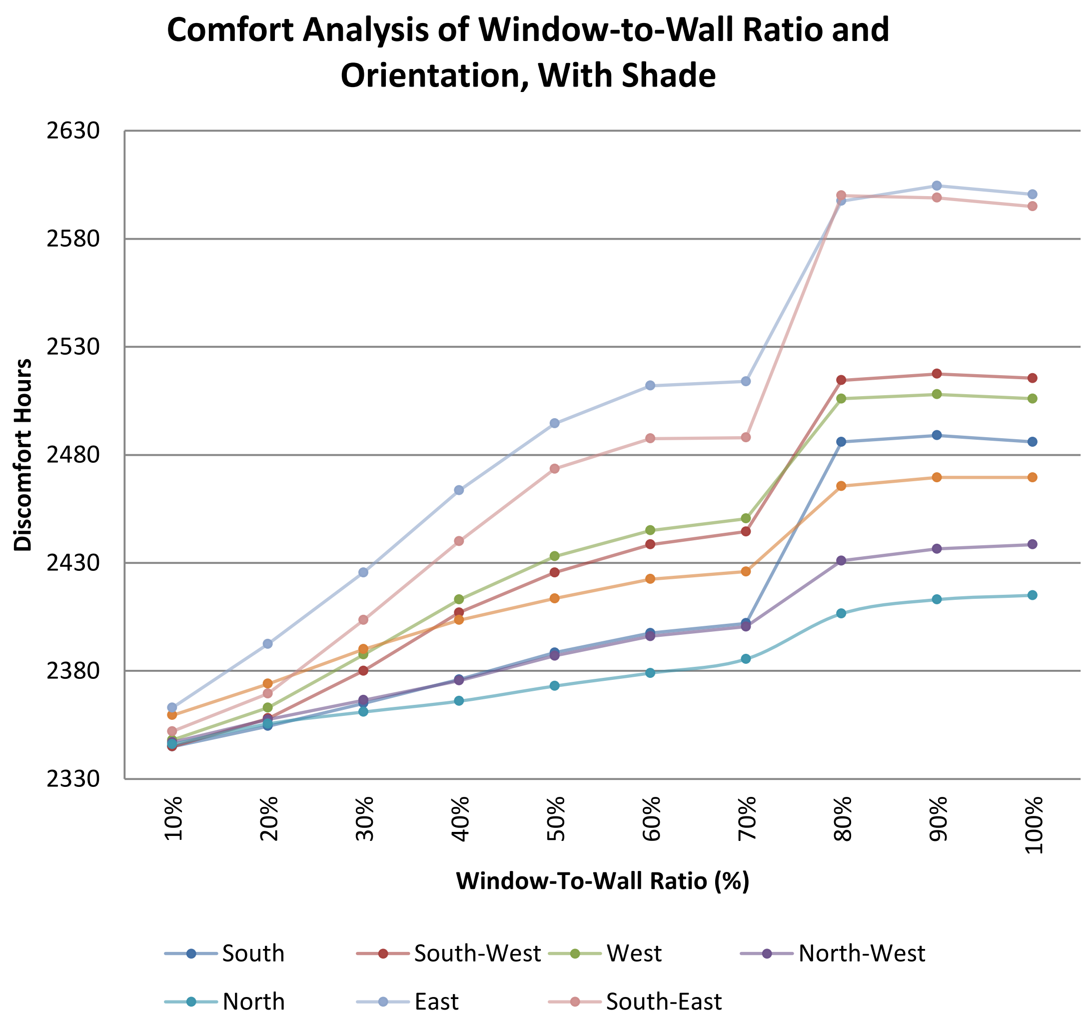
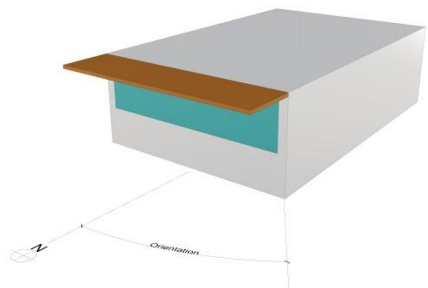
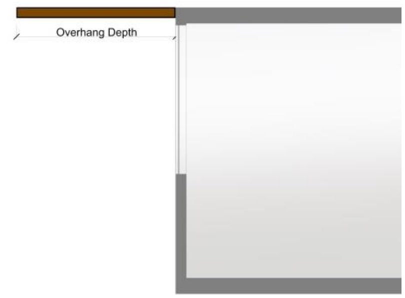


Figure 111: Window-to-Wall Ratio and Thermal Comfort, No Shading

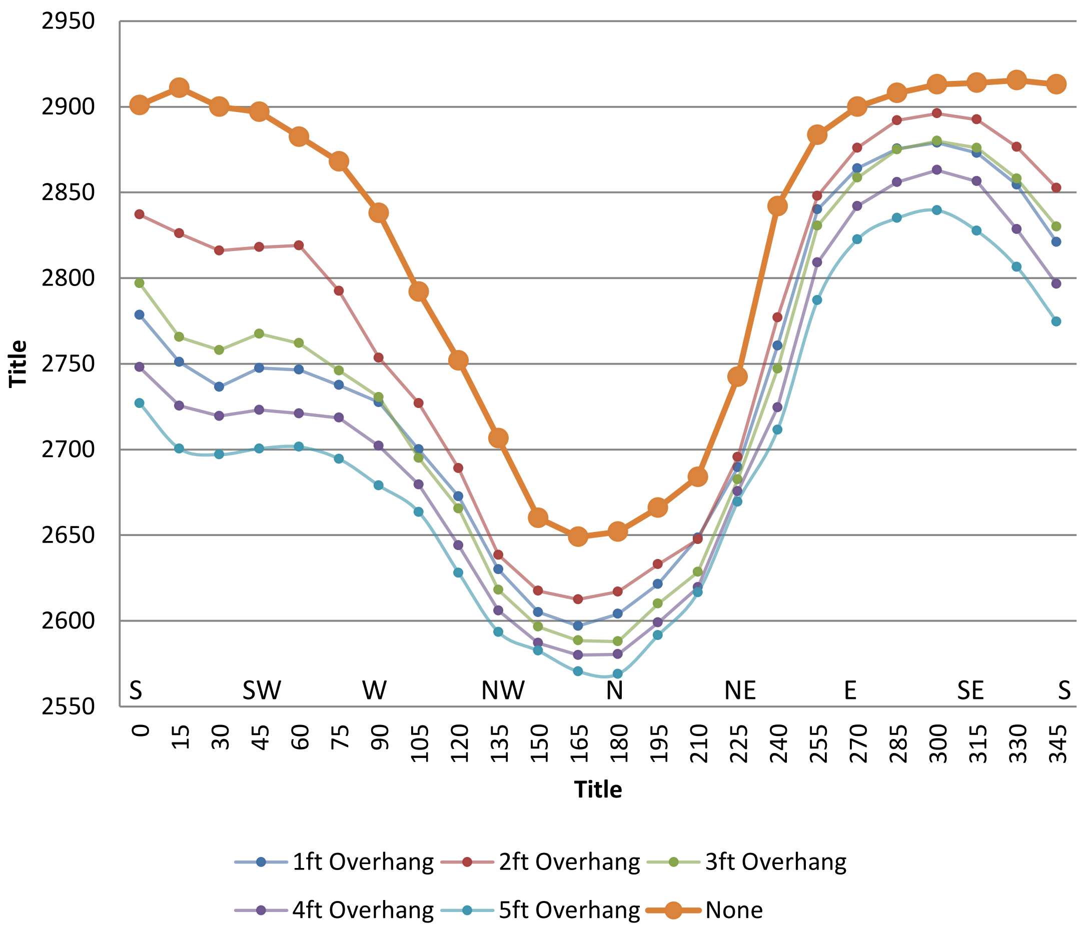
The first analysis was of window-to-wall ratio (%) or the size of the window opening in comparison to the wall and its influence in thermal comfort. The simulation was conducted on two unit models one with a 5 ft combined shading device and one without shading device and both having only a single surface exposed to the external environment. The simulation is also setup with fully naturally ventilated residential unit the overall thermal comfort for a naturally ventilated space of window sizes ranging from 10-100% in realtion to the wall. The window-to-wall ratio is asessed in all orrientation for both with and without shading. The results determine that as the window-to-wall ratio(%) increase, discomfort hours also rises. Thie results are similar for both with and without shades as well as every orientation, although the orientation does make a difference as far as the amount of discomfort hours, with the south, south-east, east, south west and the West orientation having the larger discomfort hours in relation to the window-to-wall ratio followed by North-East, North-West and North. This makes sence since the South, South-East, East, South West and the West facades have the higher direct solar gains as previously measured (Figure 106). The shaded unit however did show some significant results, indicating that there is a large spike in discomfort hours after 70% of window-to-wall ratio. This helps to determine the proper window size at any orientation.

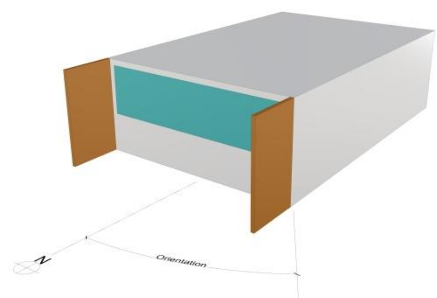
The following tables will provide the results of the parametric comparison of the overhang, fins and combination shading devices in depths of 1-5ft and orientation 0-360 degrees with 0 and 360 degrees representing south. Prototype 1 consists of facades facing south, east, north, north-west, north-east and south-east which will be pointed out on the charts.

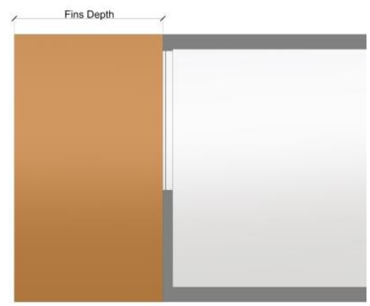


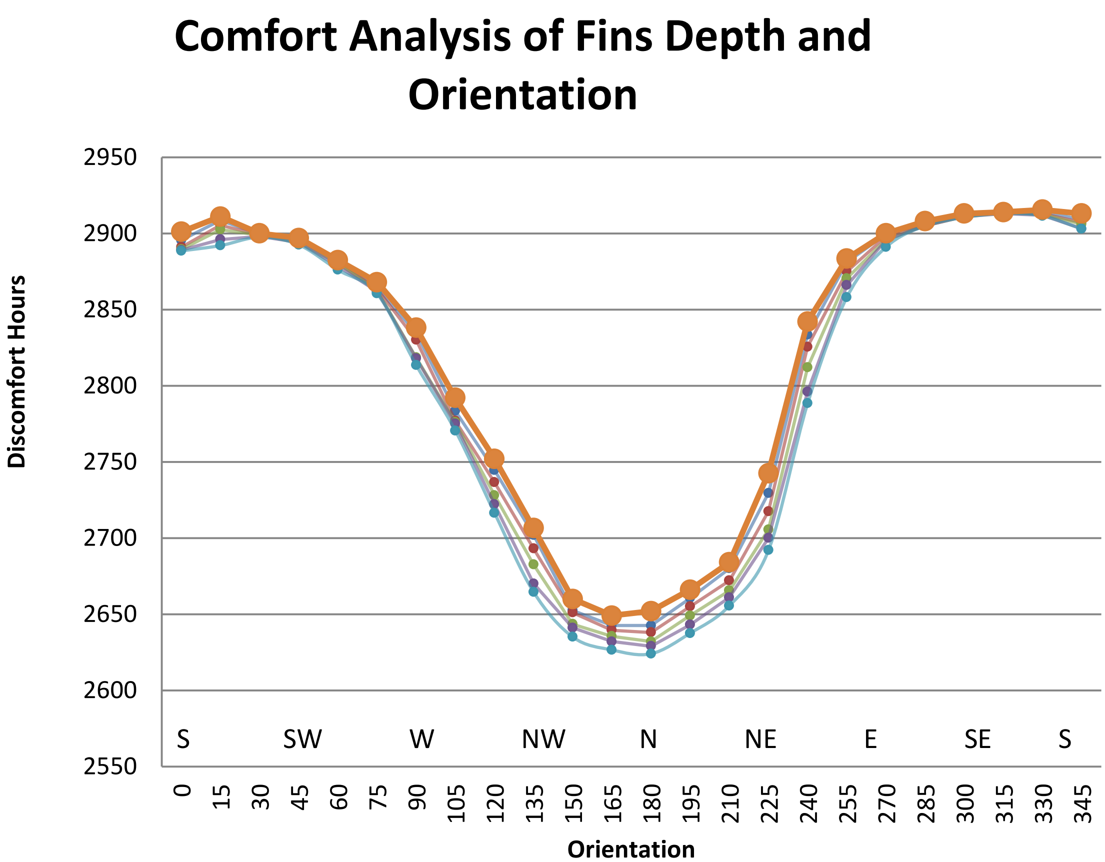


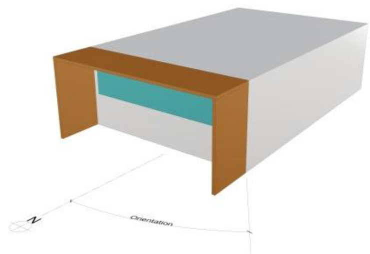
Comfort Analysis of Overhang Depth and Orientation

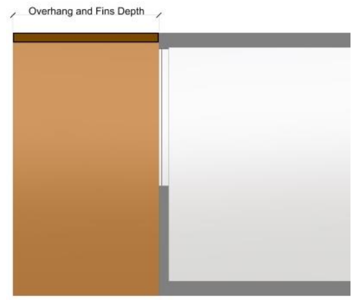



N
Orientation

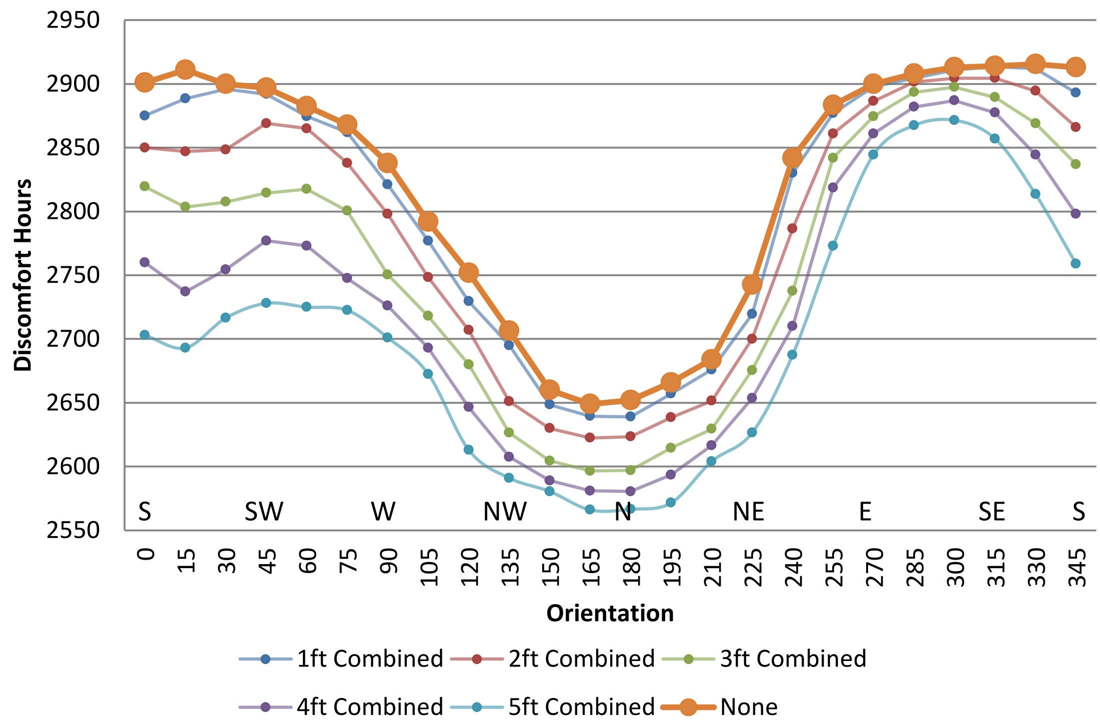

Fins Depth

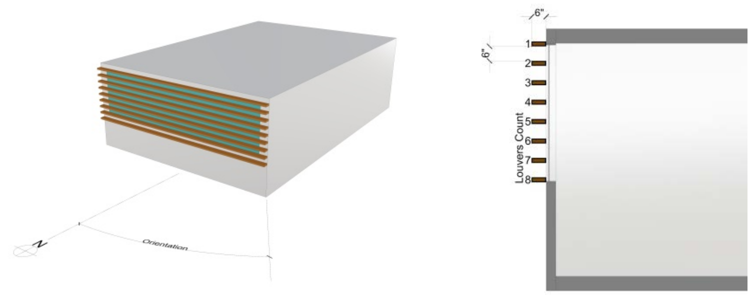

Comfort Analysis of Fins Depth and Orientation
2950
2900
2850
2800
2750
2700
2650
2600
2550
Discomfort Hours
S
SW
W
NW
N
NE
E
SE
S
0
15
30
45
60
75
90
105
120
135
150
165
180
195
210
225
240
255
270
285
300
315
330
345
Orientation
1ft Fins
2ft Fins
3ft Fins
4ft Fins
5ft Fins
None

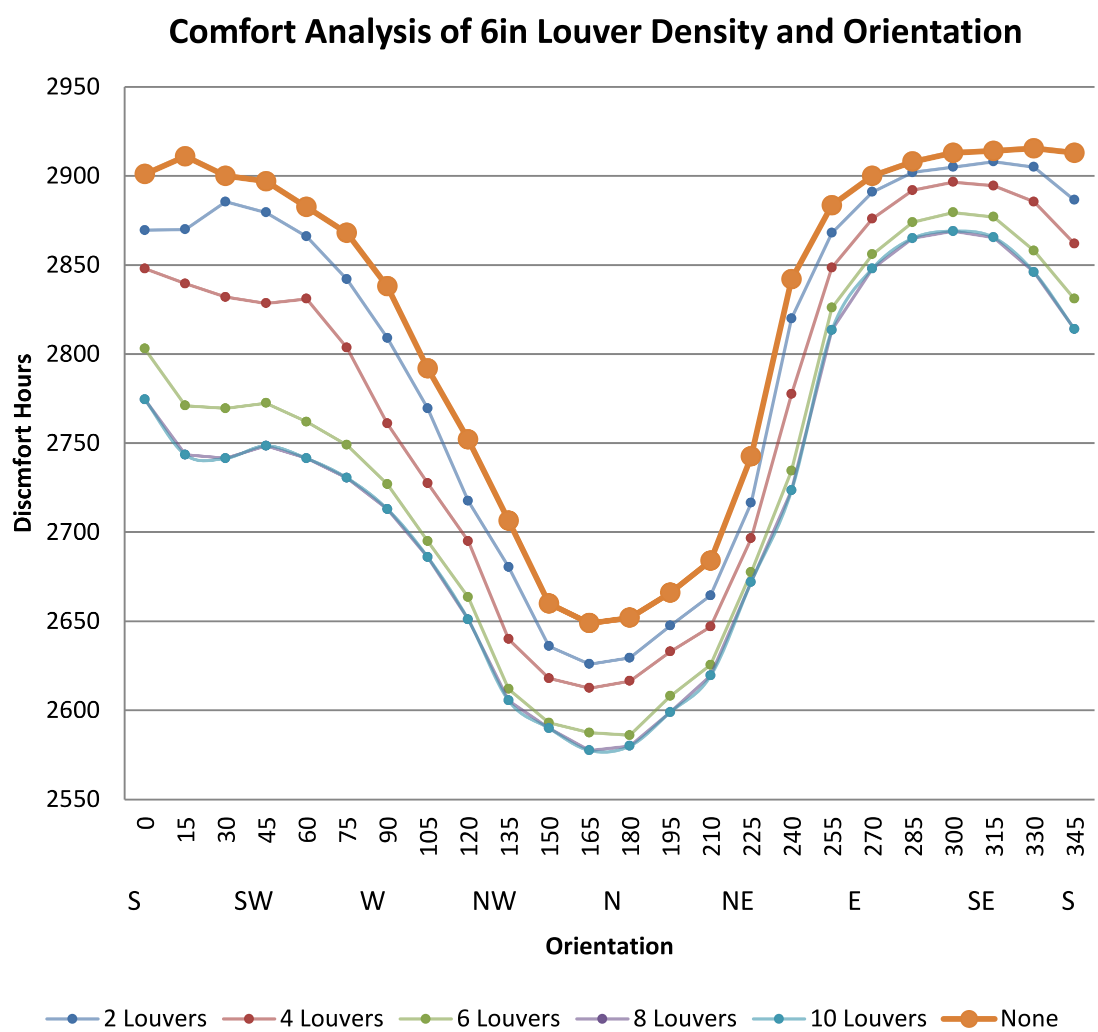




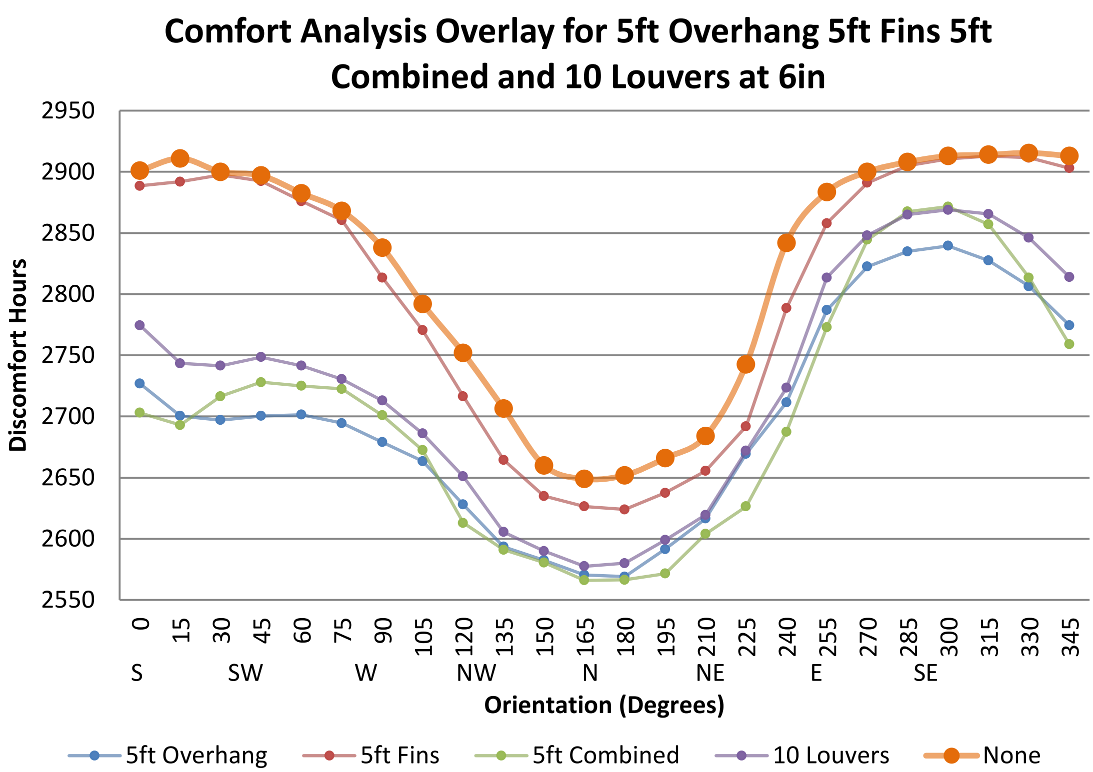
Comfort Analysis of Combined Overhang and Fins Depth and Orientation







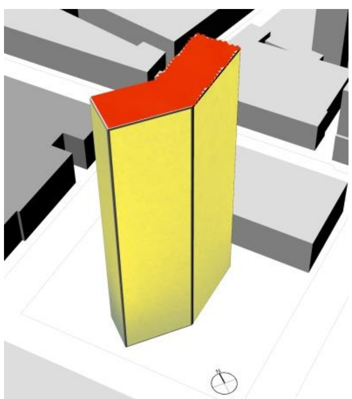
The result of the parametric simulation indicate that the impacts of shading device is very significant in achieving a thermally comfortable environment. The horizontal shading device or overhang have substantial impacts to reducing discomfort hours especially as the depth of the shade increases. The vertical shading device or the fins also show that thermal comfort improves as the depth of the shade increases. However, the result for the fins also determins that the fins have very little impact in improving comfort and also verry minimal differences as far as depth and performance. The combined horizontal and vertical shading device have similar impacts to condition as the overhang, the larger the depth of the shading device the more comfortable the space cecomes. Looking at the louvers and density of the shading device, the larger the amount of lovers there are, the better the performace of the shading device.

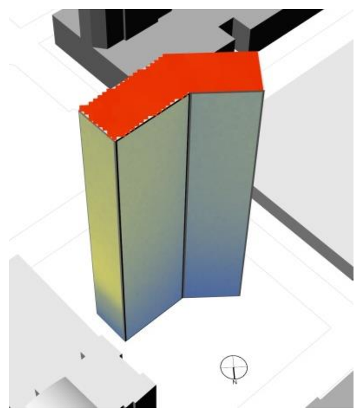


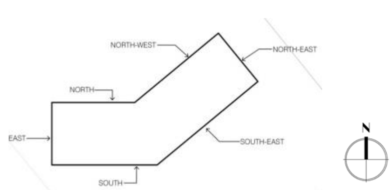
When comparing shading devices to each other, with the most effective depth or density including 5ft overhang, 5ft fins, 5ft combined and 10 louvers, the overhang, the combined and the louvers show the larger impact in reducing discomfort hours.

In addition to the thermal comfort assessment, direct solar exposure was also measured to further assess the performance of the shading device. In this scenario the shading device is composed of combined horizontal and vertical shading system.

PROTOTYPE 1

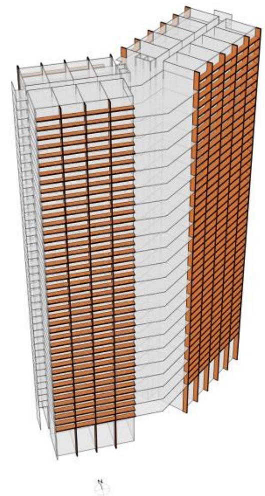


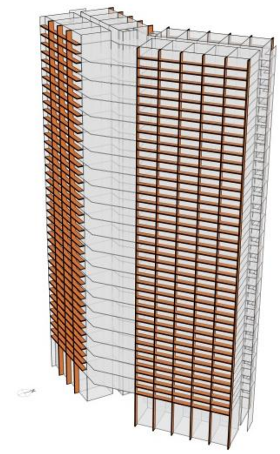


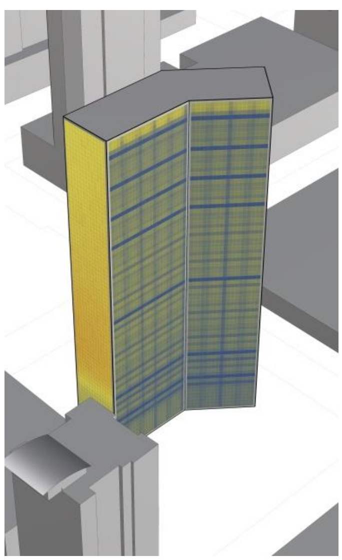


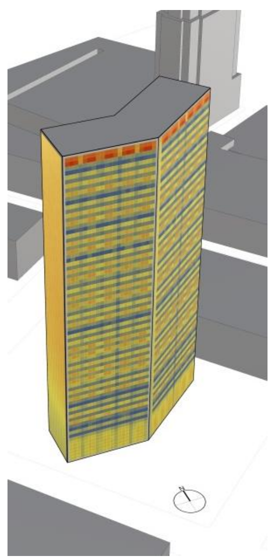
SOUTH:	**782.84** kWh/m2
SOUTH-EAST:	**753.46** kWh/m2
NORTH-EAST:	**545.57** kWh/m2
NORTH-WEST:	**381.65** kWh/m2
NORTH:	**327.06** kWh/m2
EAST:	**620.42** kWh/m2

Horizontal and vertical shading, 5ft.

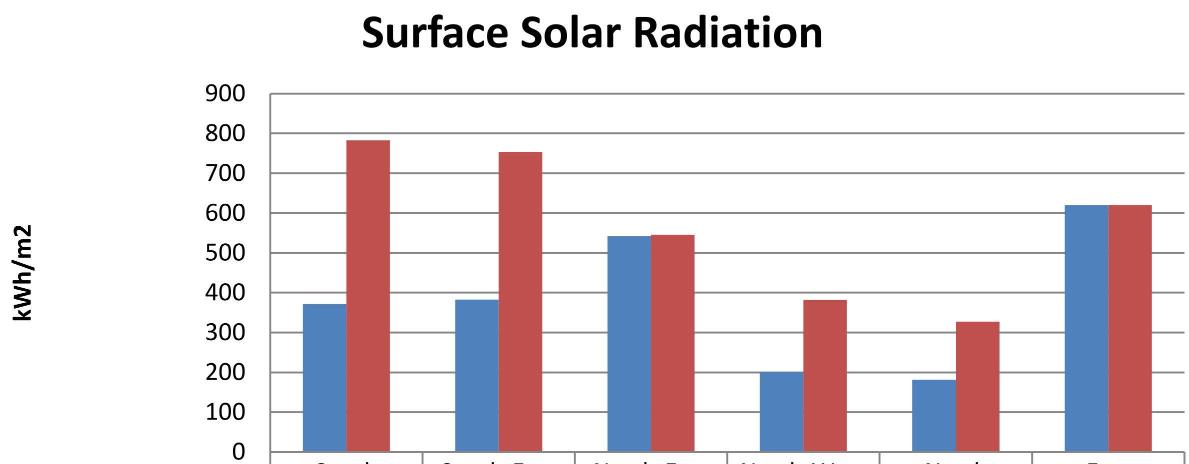








SOUTH:	**371.71** kWh/m2
SOUTH-EAST:	**382.76** kWh/m2
NORTH-EAST:	**541.62** kWh/m2
NORTH-WEST:	**200.19** kWh/m2
NORTH:	**180.87** kWh/m2
EAST:	**619.54** kWh/m2



	South	South-East	North-East	North-West	North	East
With Brise-Soleil	371.71	382.76	541.62	200.19	180.87	619.54
Without Brise-Soleil	782.84	753.46	545.57	381.65	327.06	620.42
	-52.5%	-50%	Un-shaded	-47.5%	-45%	Un-shaded

Figure 112: Surface Solar radiation, with and Without Shading Device

The results determine that the Performance of the shading device is very effective, reducing direct solar radiation on all major surfaces of the building by half on average.

In conclusion shading devices provides an effective response to improving the thermal comfort within the interior spaces. The most effective shading device is the 5ft overhang in comparison to the fins, but a combination of the two is more effective in both improving thermal comfort and reducing the direct solar impact.

In addition to providing shades the overhang functions also as a lanai space, which offers an outdoor environment on the façade for gardening or for scenic viewing, and for potential adaptive strategy. Lanai spaces are prominent in the building, sky lanais which are community lanais are major elements that are incorporated into the building design with diverse functions.

Vertical Programming Zones

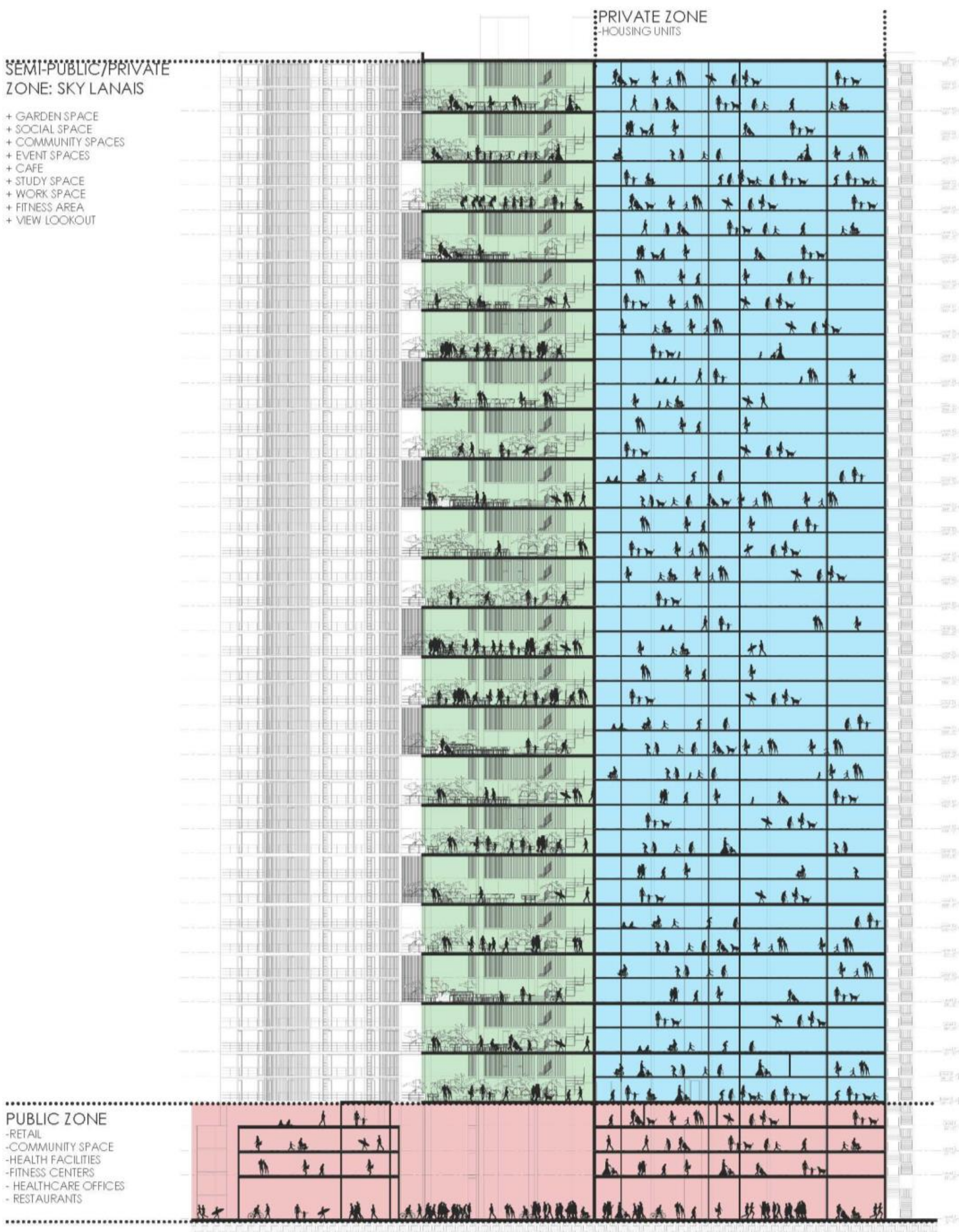
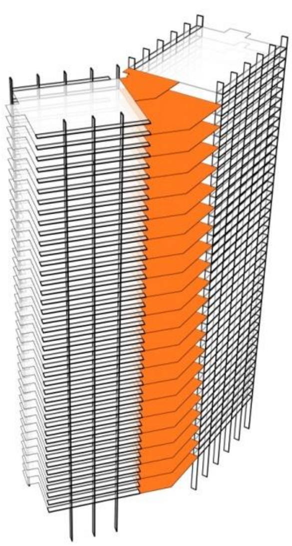


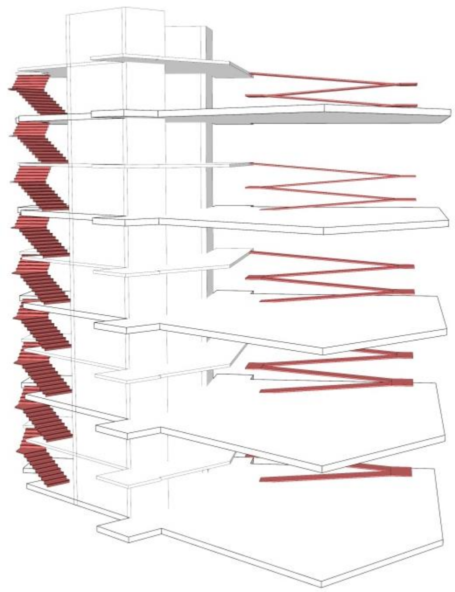
Figure 113: Building Section and Program Zones

The Ideal programming for the high-rise residential is the mixed-used building, which consists of diverse vertical programming. The benefits of having such vertical programming are that it promotes social inclusiveness between residents including public interaction within a high-rise typology; these are prominent in the public zones and especially in the sky lanais.

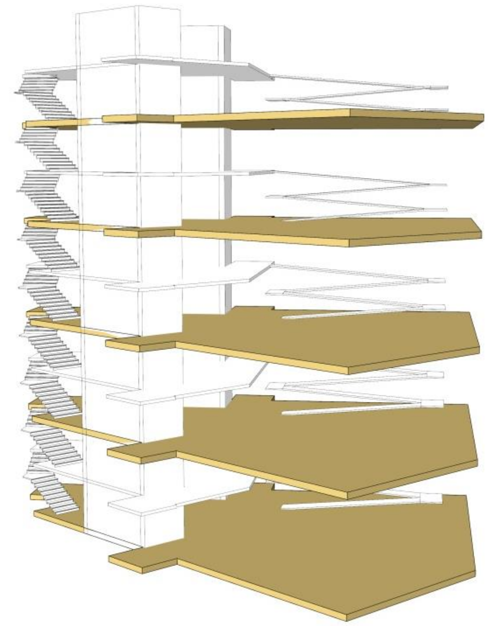
The sky lanai is an essential element for the residential high-rise building specifically because of its flexibility in its function. The sky lanais function as community space that allows for various types of programs essential to the occupants such as gardening, lounge, fitness, or a café with study and work areas.

Sky Lanais and the Skip Stop Circulation

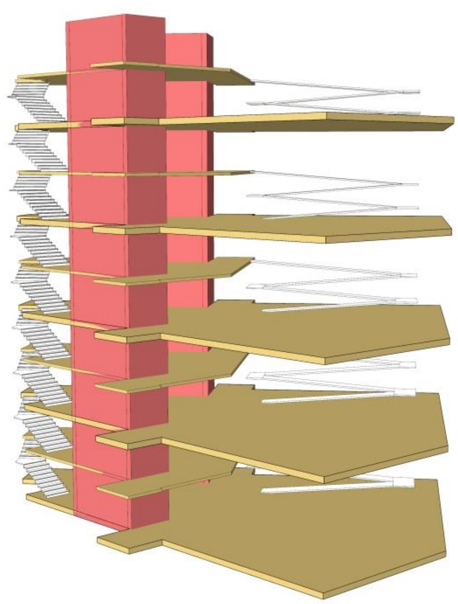




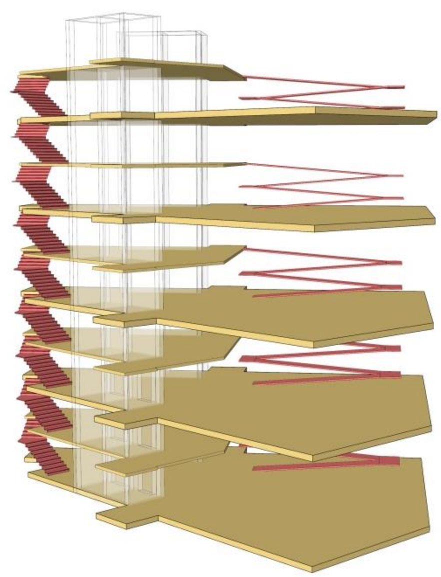
Stairs and Ramp Circulation



Sky Lanai

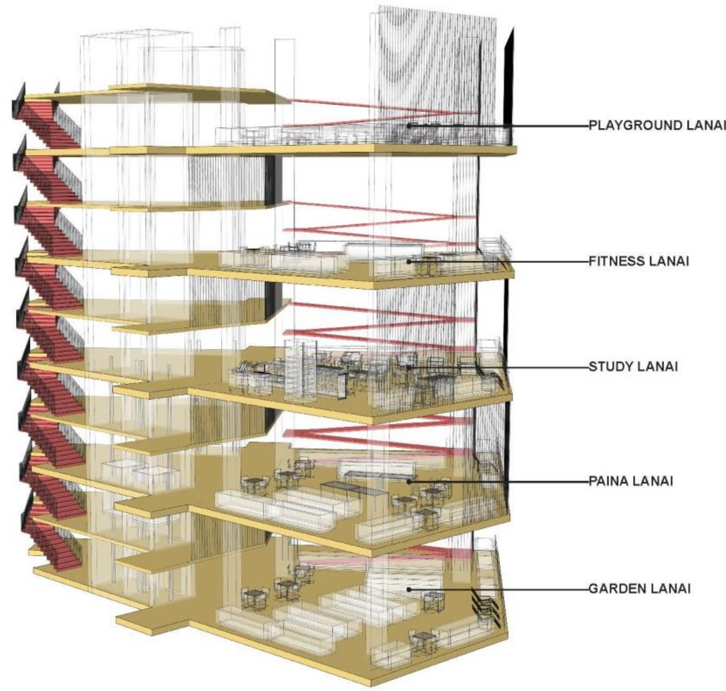


Skip Stop Elevators and Sky Lanais

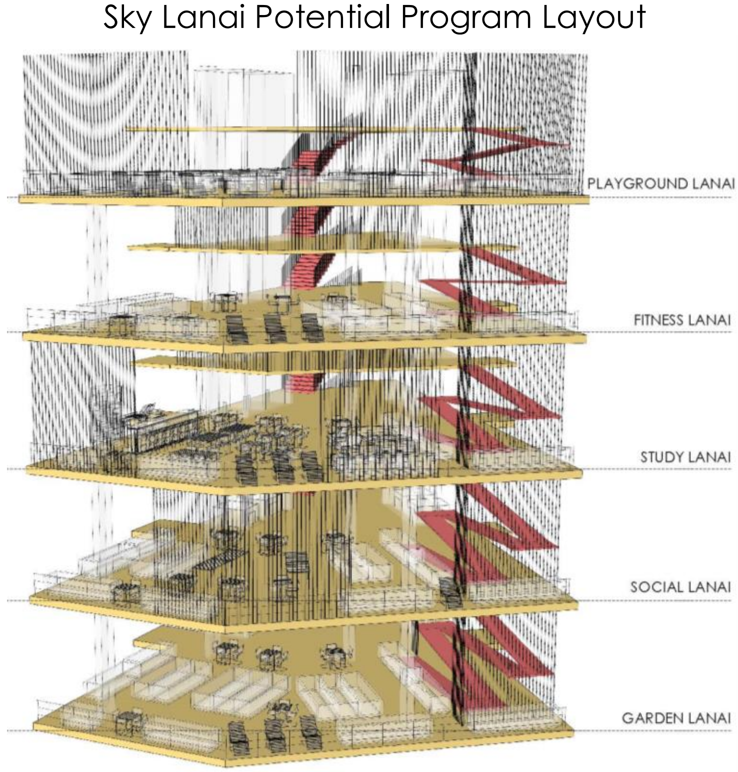


Skip Stop Circulation Connecting to the Sky Lanais

Figure 114: Sky Lanai and Skip Stop Circulation and Sky Lanais



Sky Lanai Potential Program Layout



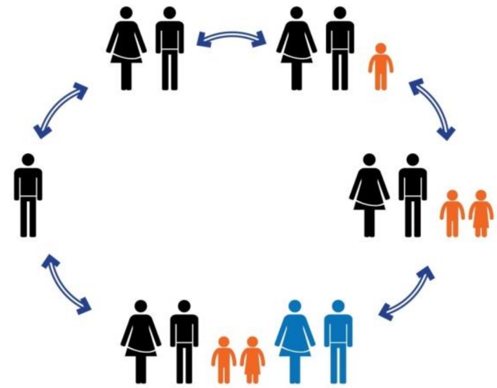
Sky Lanai Exterior Perspective

Figure 115: Sky Lanai Programming

Figure 116: Prototype 2 Sky Lanai Perspective Rendering

The primary purpose of the sky lanais is to increase the social inclusiveness within the building but also to provide outdoor community spaces for the occupants. The primary circulation for the high-rise is the skip-stop elevator, which stops only at every other floor. The floor on which the elevator stops is on the same level as the sky lanais, and connects to the upper level through stairs and ramps (Figure 114). The benefits of incorporating the skip stop circulation system are that it improves social quality by creating accidental interaction between the occupants and also the physical health by promoting movement and activeness. Every other floor consists of a sky lanai therefore is easily accessible from the individual units, the sky lanais are double ceiling height to create an open space exposed to the outdoor environment. Each sky lanai could have a variety of function which again encourages the occupants to be active (Figure 115).

Multigenerational Units



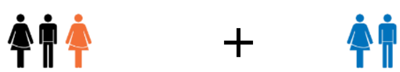
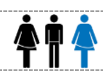
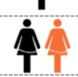
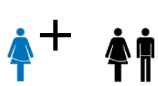
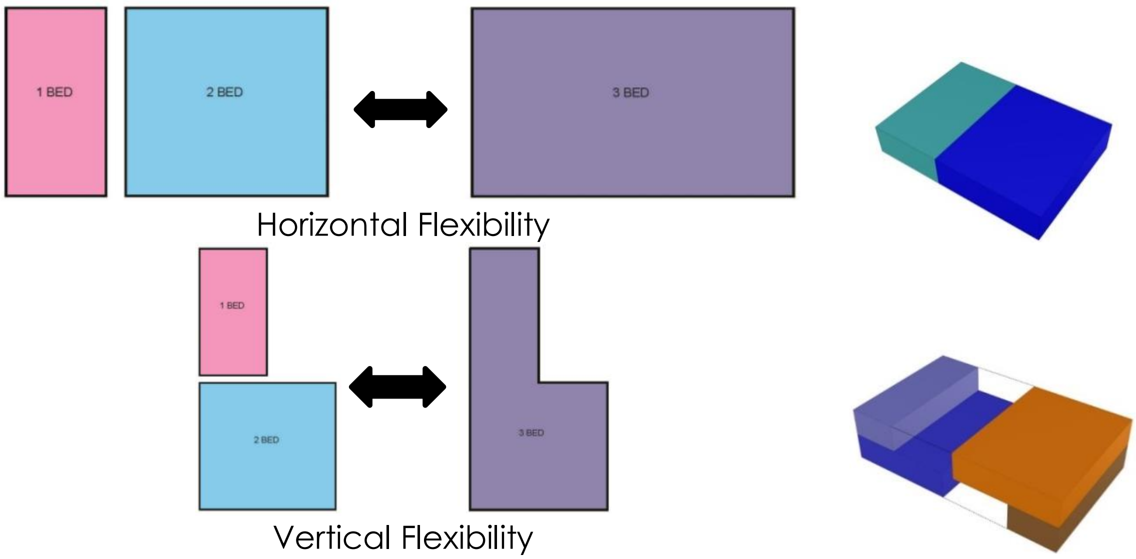
Family Size	Family transformation Scenarios	Bedrooms
	Couple	1
	Couple have one or two children Nuclear Family	2
	Extended family member; grandparent(s) who can no longer live independently joins the family. Nuclear + Grandparents	3
	The eldest child goes to college and moves out. Couple + Child + Grandparents	3
	All children has moved out Couple + Grandparents	2
	Passing away of one grandparent	2
	Couple divorce Single + Grandparent	2
	Passing away of grandparent Single	1
	Child moving back in with parent	2
	Older Child finds a partner and lives with Parent	3

Table 4: Family Transformations

Unit Layouts



The design goal for the units is to create an environment that adapts to the changes and transformation of a family (Table 4). This is achieved through flexible elements in both the unit and space level. The following section will investigate various options of units that are flexible and able to adapt to multiple transformation of families.

Layout 1 & 2: Spatial Flexibility and Scenarios

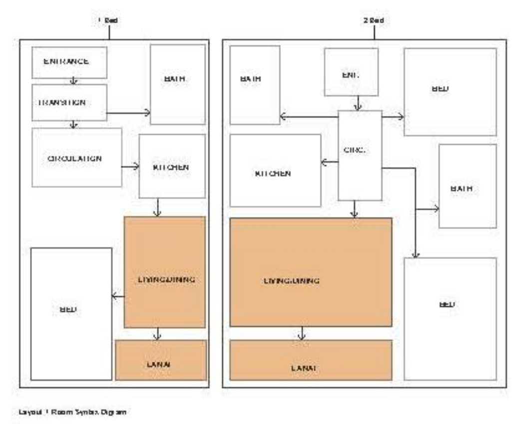
Layout 1 & 2

Couple | Nuclear

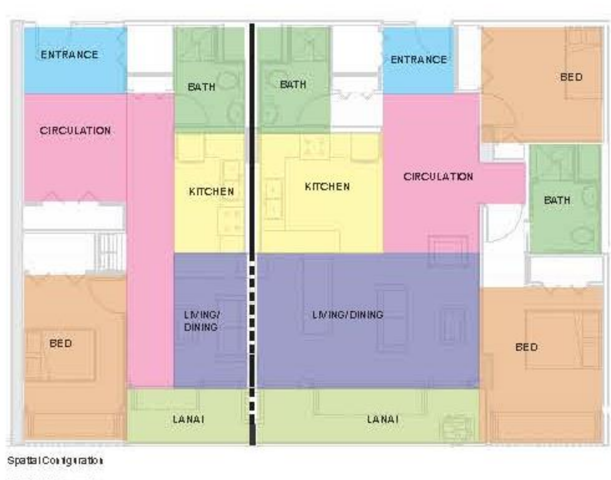
Single Parent | Single with Extended

Widowed Senior | Single Parent with older Child

Spatial Configuration: 1 Bed Unit + 2 Bed Unit



Syntax Diagram

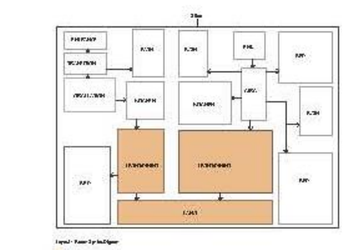


Layout 1 & 2

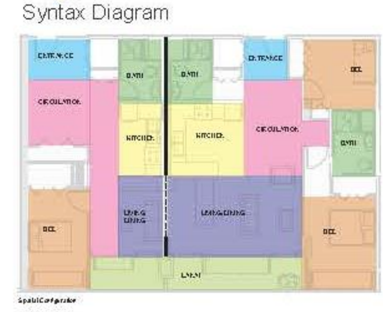
\+ Multigenerational

Single Parent + Older Child with Partner

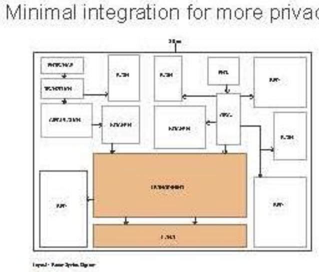
Spatial Configuration: 3 Bed Unit



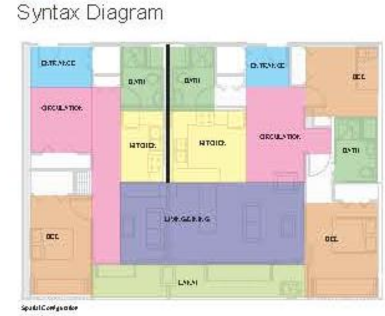
Syntax Diagram



Minimal integration for more privacy



Syntax Diagram



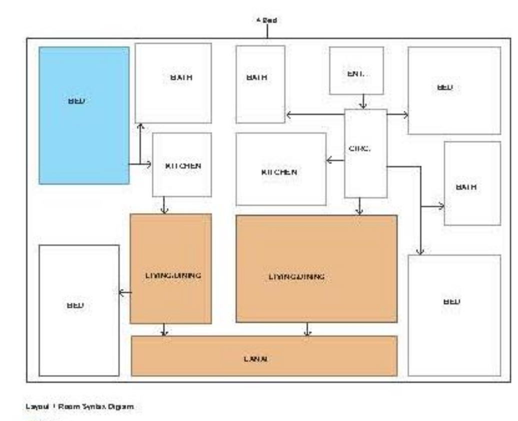
Fully Integrated

Layout 1 & 2

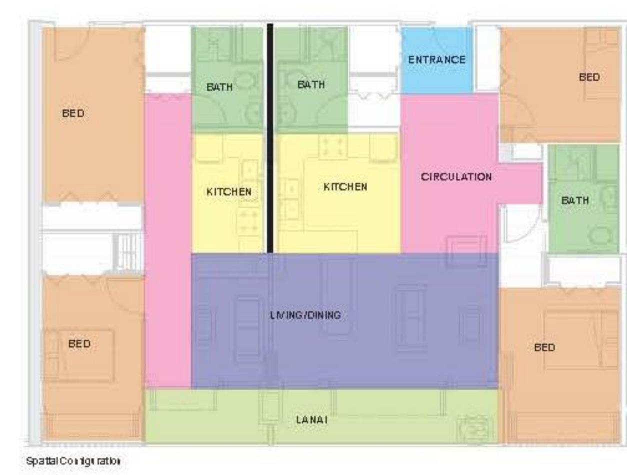
\+ Multigenerational

\+ Multigenerational

Spatial Configuration: 4 Bed Unit



Allowable 4th bedroom zone

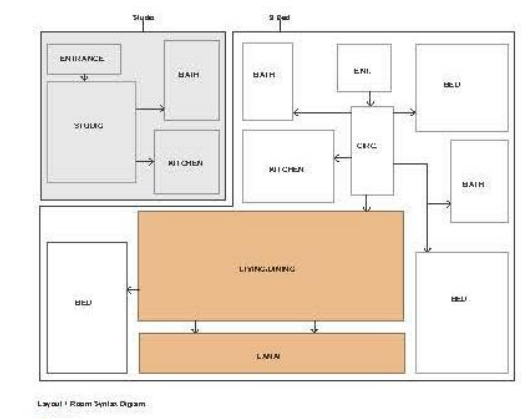


Layout 1 & 2

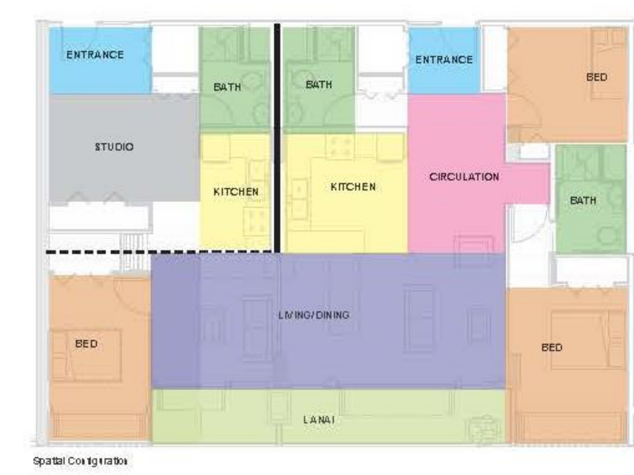
Single | Multigenerational

Single | Couple + Extended Member

Spatial Configuration: 3 Bed Unit + Studio

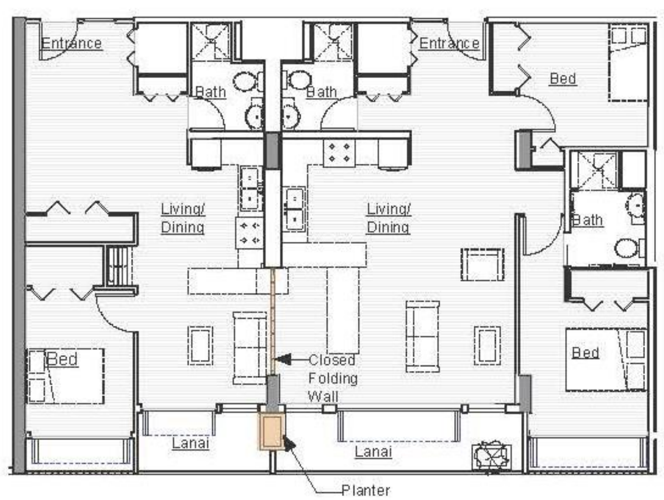


Zones Allowable for single occupant Studio

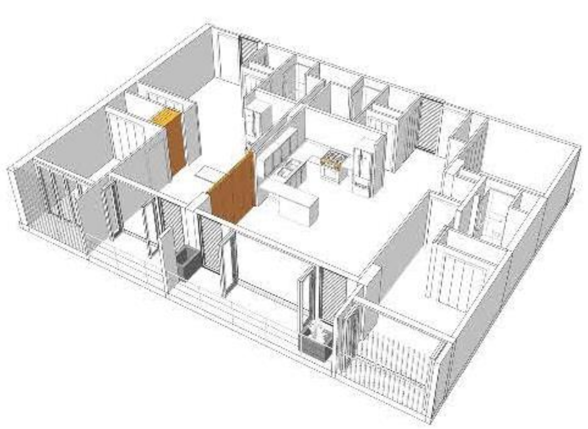


Layout 1: Floor Plan and Flexible Components

Layout 1A

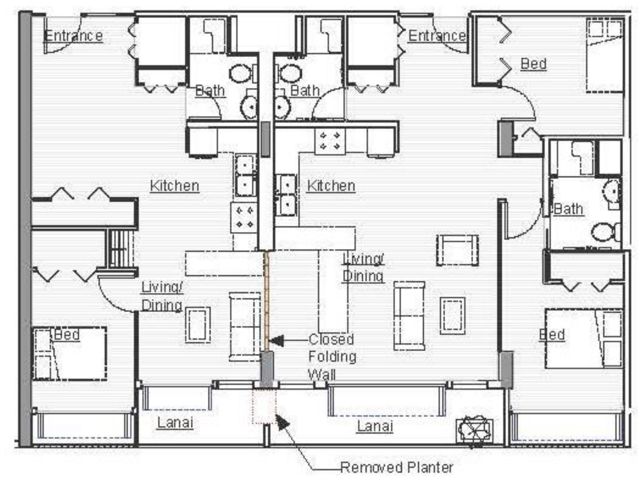


1 bed and 2 bedroom Unit

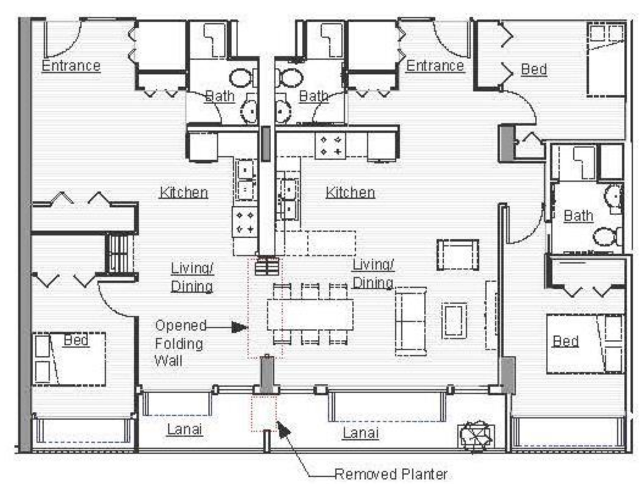


Folding partitions and movable planters

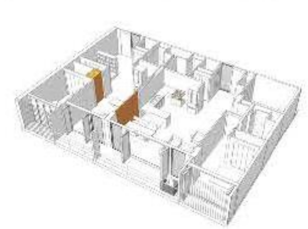
Layout 1B

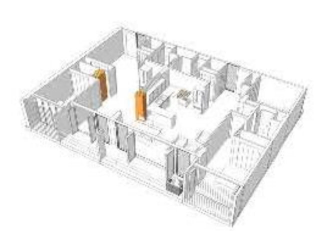


3 bedroom Unit with minimal connection for more privacy



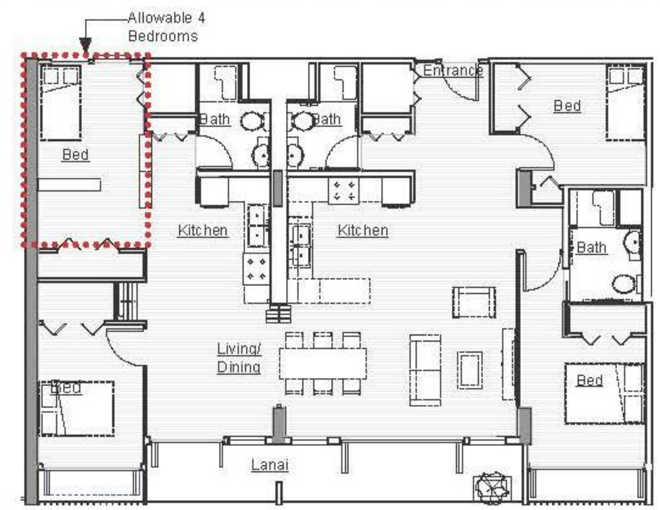
3 bedroom Unit with minimal connection for more privacy



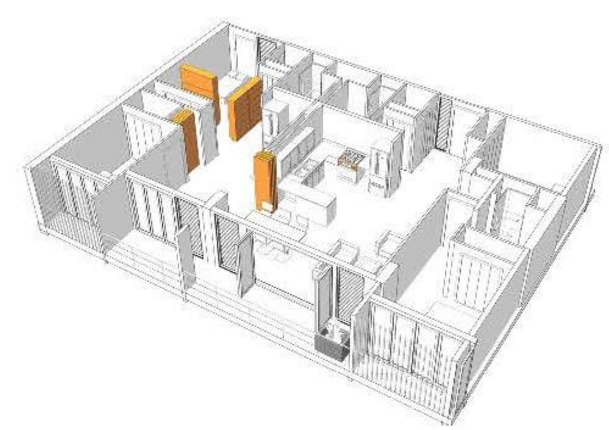


Folding partitions and movable planters

Layout 1C

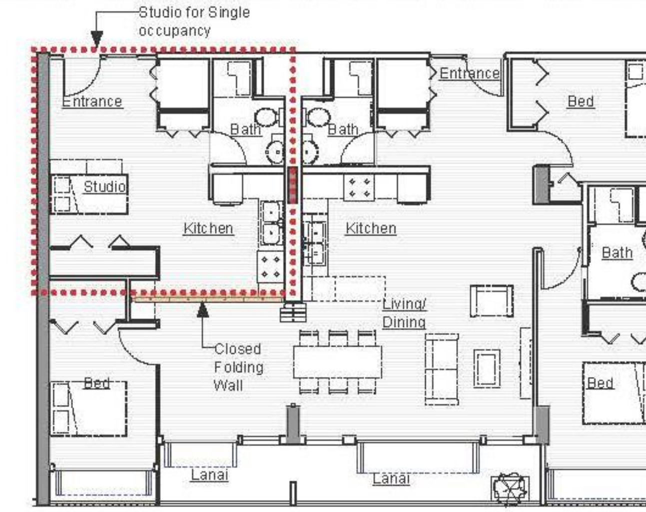


Full integration of units

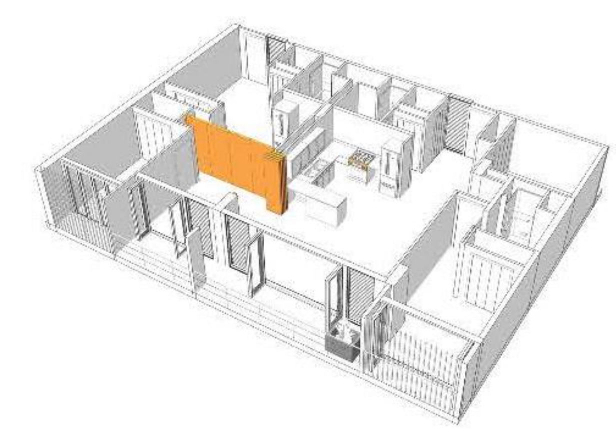


Folding partitions with added shelf partitions

Layout 1D



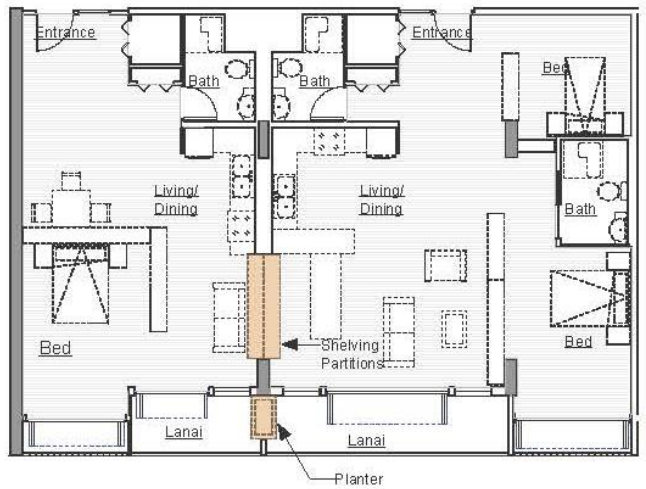
Studio created for potential single person rental



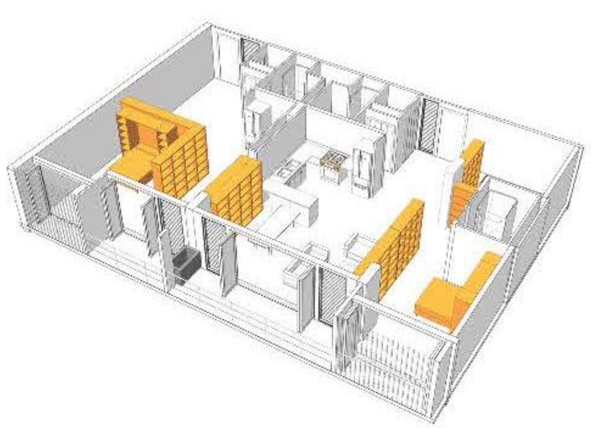
Folding partitions

Layout 2: Floor Plan and Flexible Components

Layout 2A

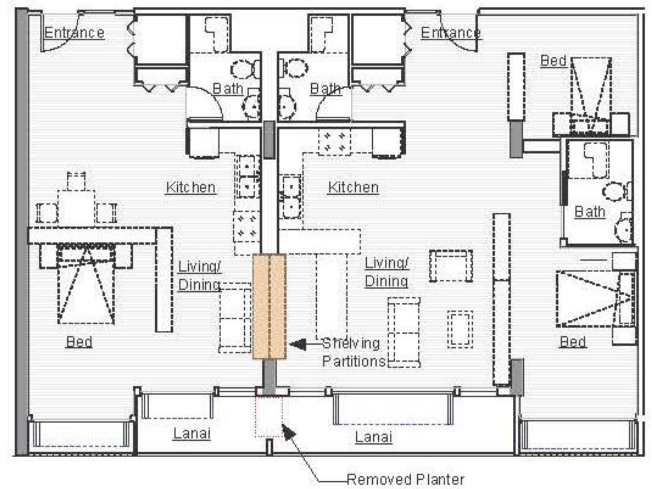


1 bed and 2 bedroom Unit

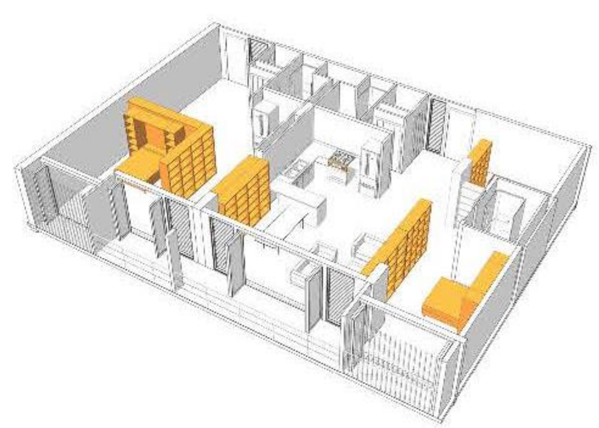


Shelf partitions, folding wall beds and movable planters

Layout 2B

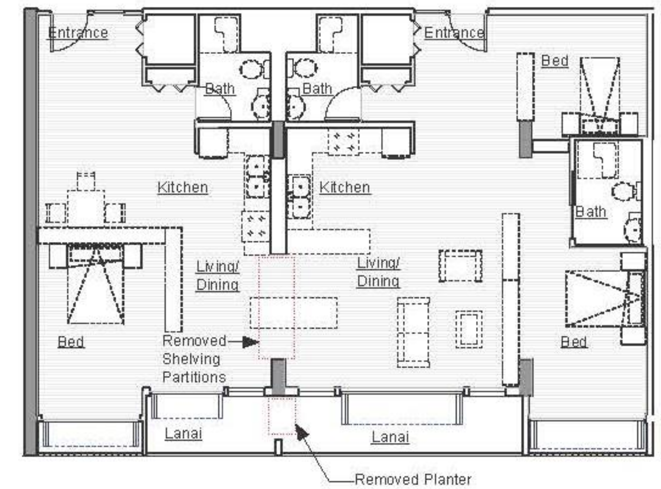


3 bedroom Unit with minimal connection for more privacy

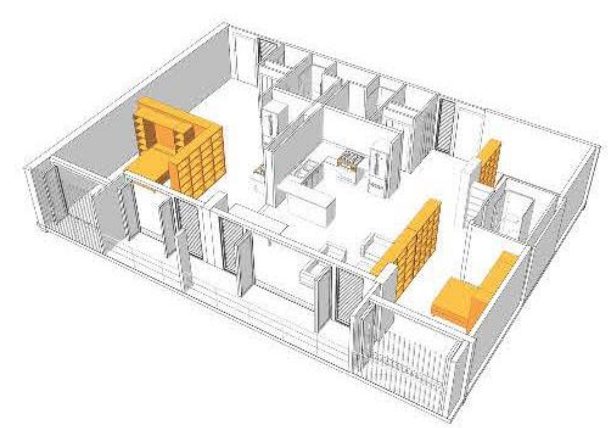


Shelf partitions and folding wall beds

Layout 2C

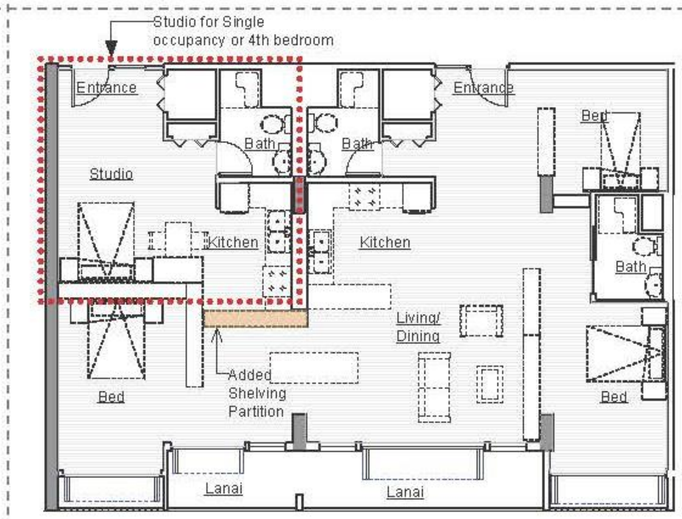


Full integration of units

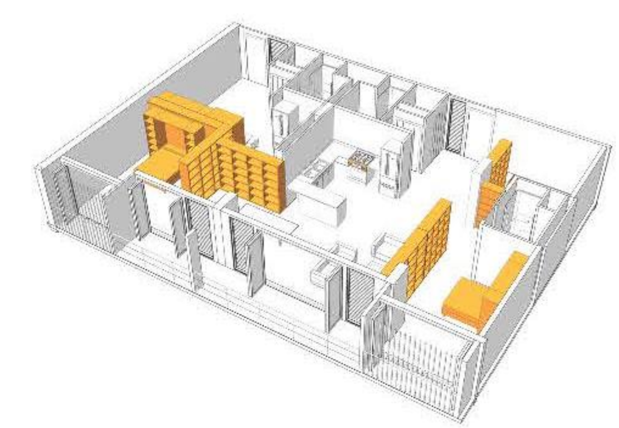


Shelf partitions and folding wall beds

Layout 2D



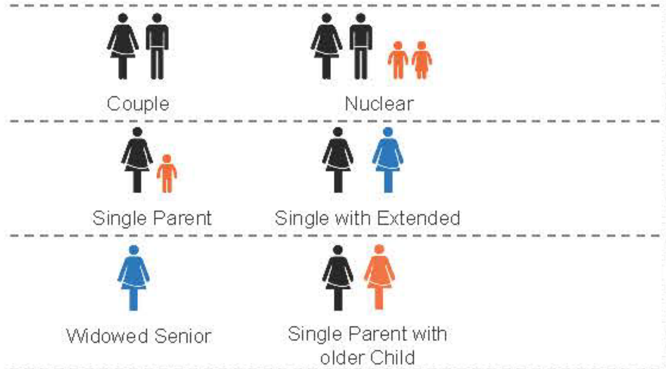
Studio created for potential single person rental



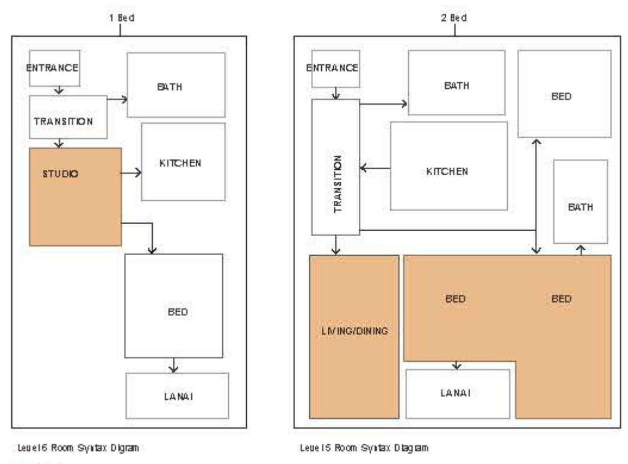
Shelf partitions and folding wall beds

Layout 3 & 4: Spatial Flexibility and Scenarios

Layout 3 & 4

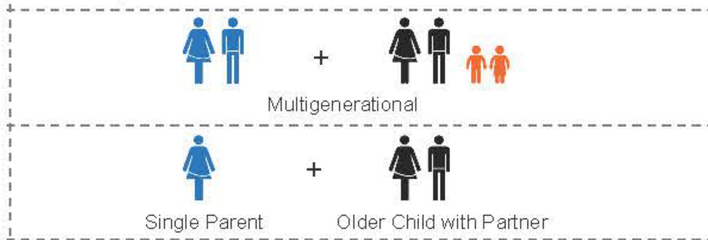


Spatial Configuration: 1 Bed Unit + 2 Bed Unit

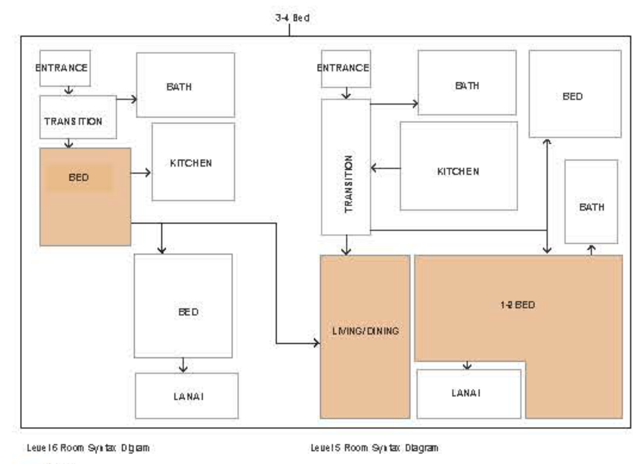


Syntax Diagram

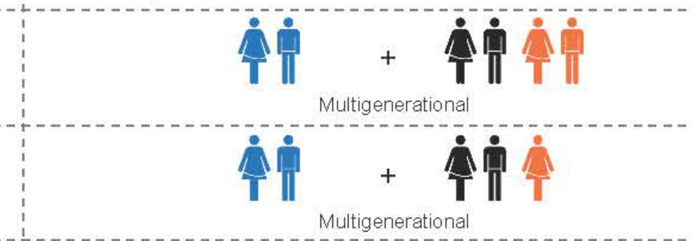
Layout 3 & 4



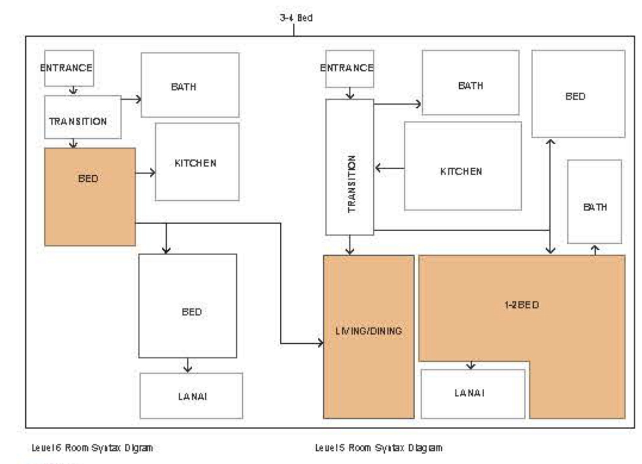
Spatial Configuration: 3 Bed Unit



Layout 3 & 4

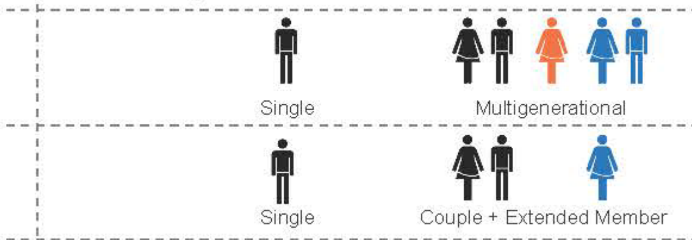


Spatial Configuration: 3 - 4 Bed Unit

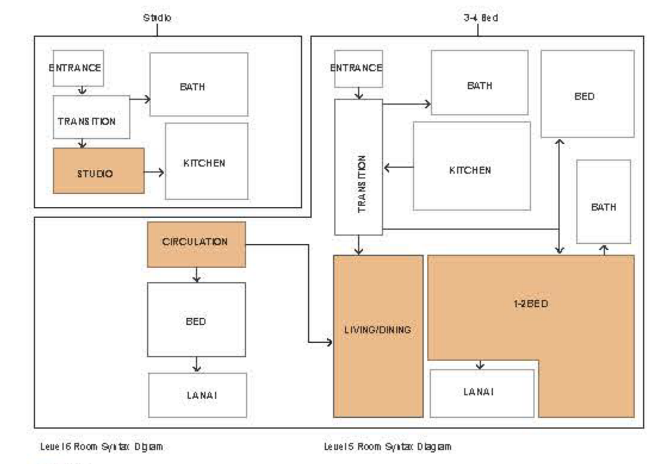


Allowable 4th bedroom zone

Layout 3 & 4



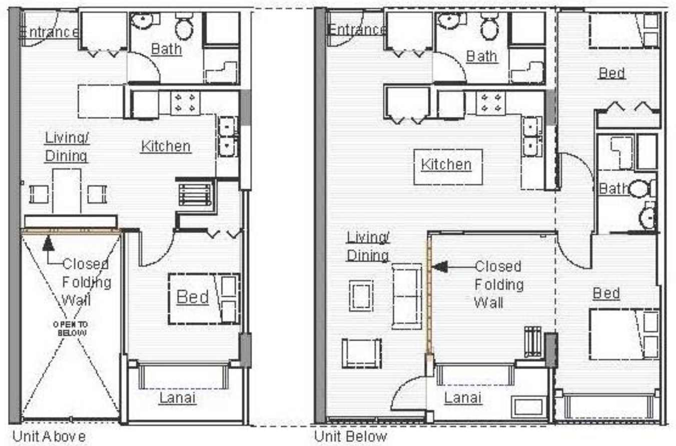
Spatial Configuration: 2-3 Bed Unit + Studio



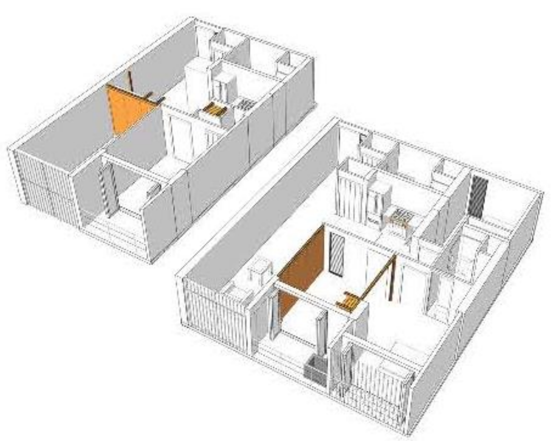
Zones Allowable for single occupant Studio

Layout 3: Floor Plan and Flexible Components

Layout 3A

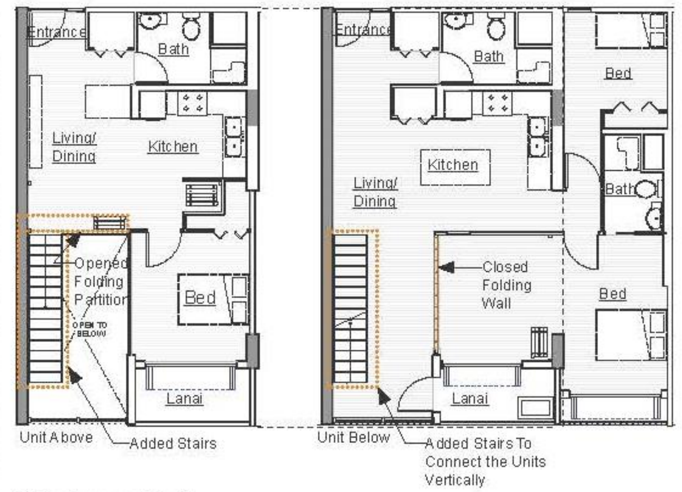


1 bed and 2 bedroom Unit

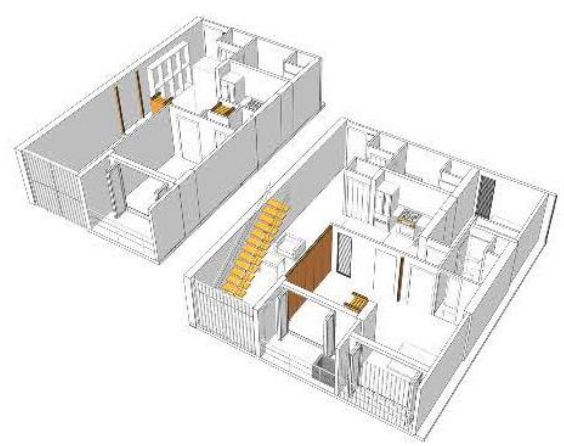


Folding Partitions

Layout 3B

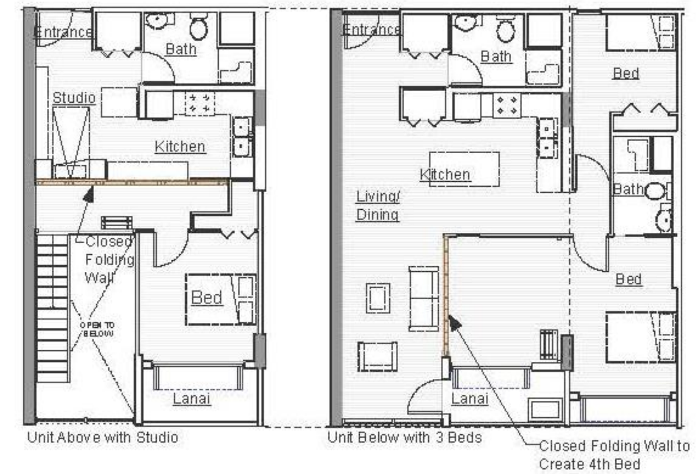


3 bedroom Unit



Folding partitions and added stairs

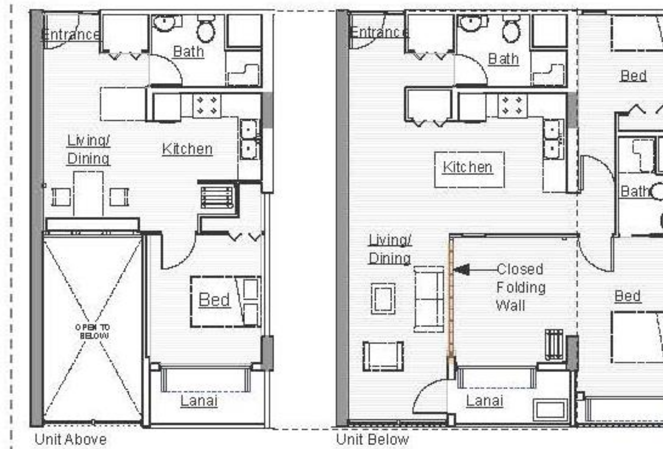
Layout 3C



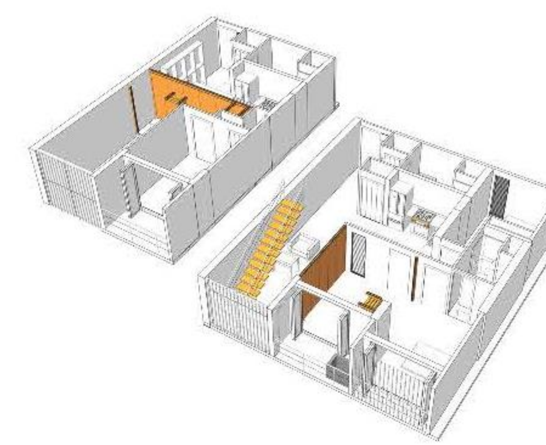
Studio and 3 Bedrooms

Folding partitions and added stairs

Layout 3D



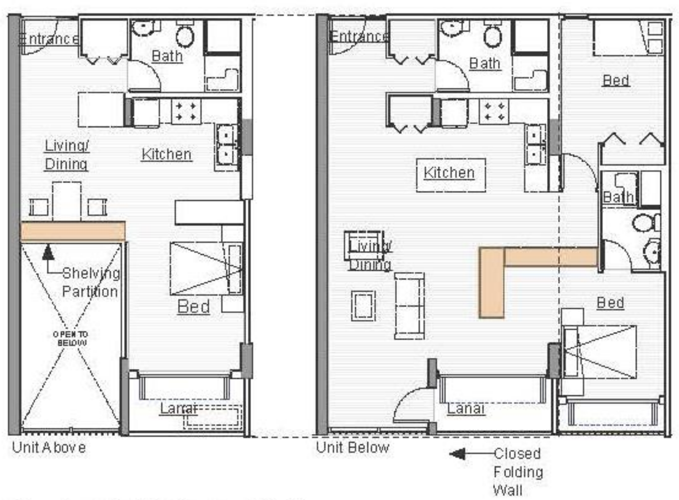
Studio and 4 Bedrooms



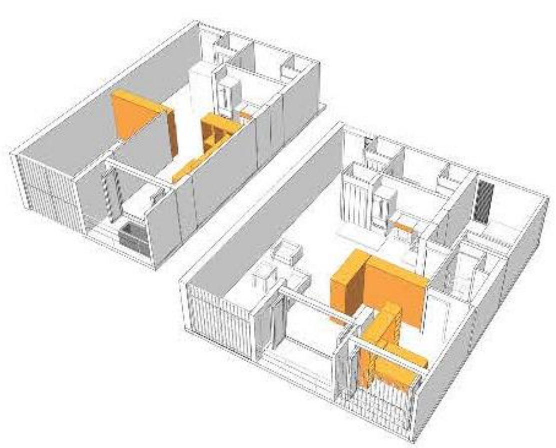
Folding partitions and added stairs

Layout 4: Floor Plan and Flexible Components

Layout 4A

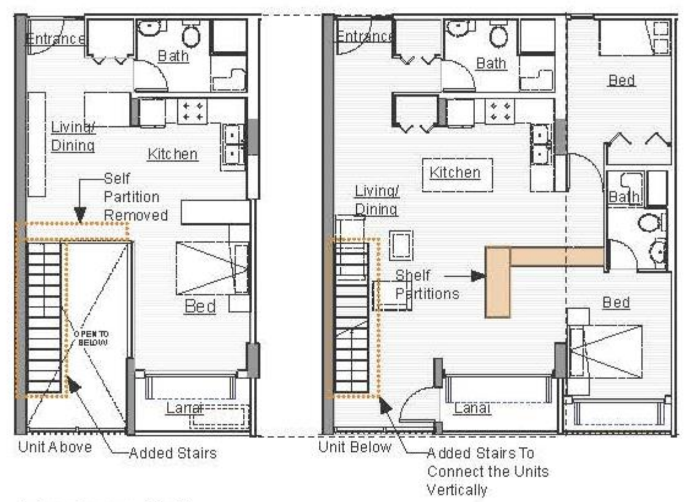


1 bed and 2 bedroom Unit

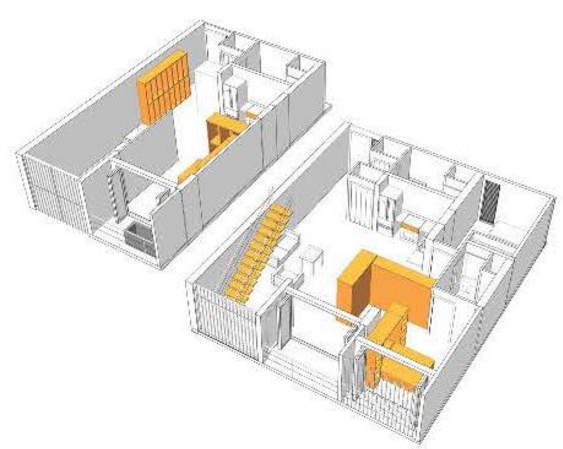


Movable Shelving Partition

Layout 4B

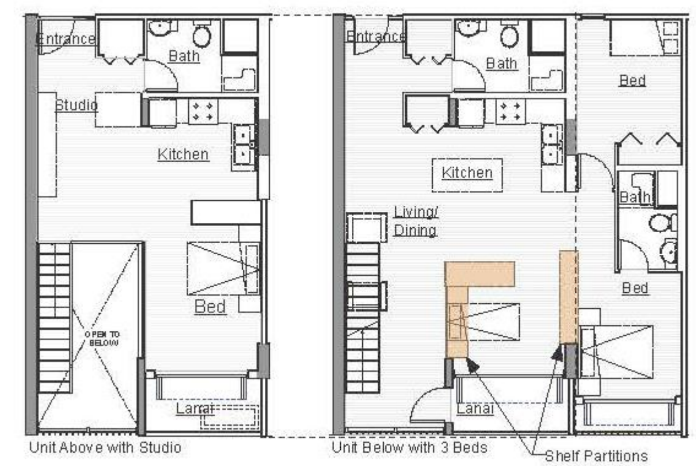


3 bedroom Unit

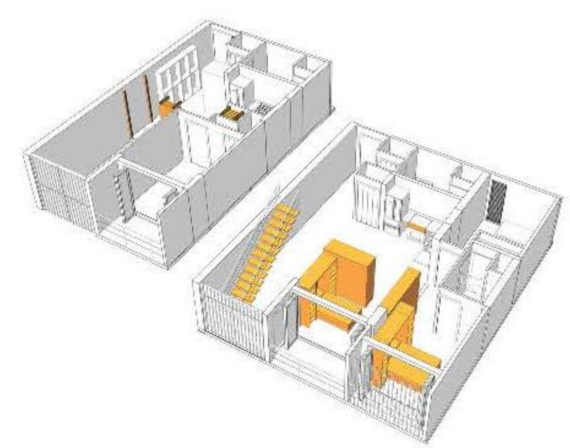


Moving shelving partition and added stairs

Layout 4C

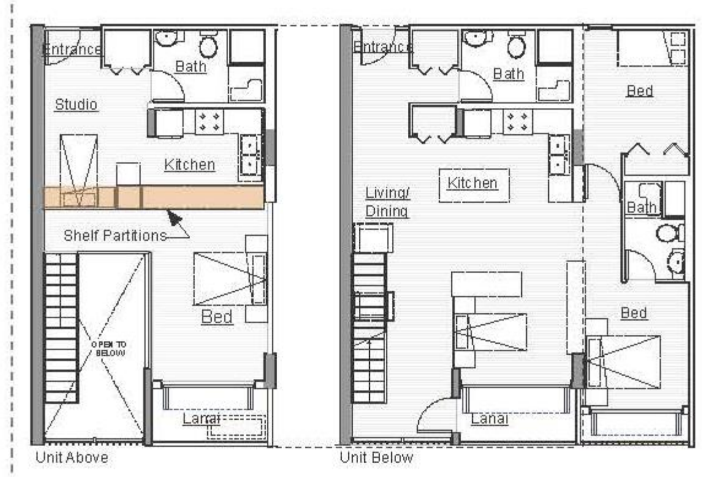


4 bedroom unit

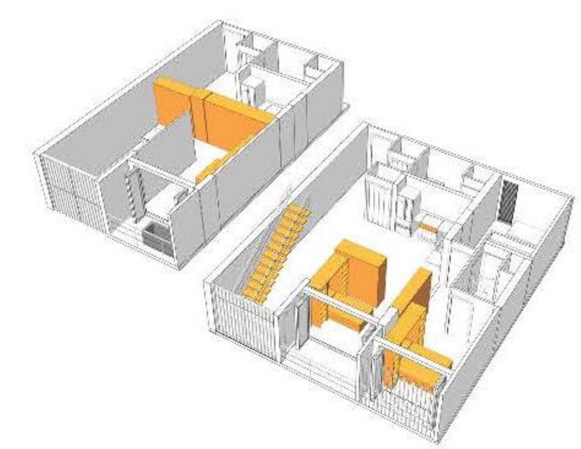


Moving shelving partition and added stairs

Layout 4D



Studio created for potential single person occupancy



Moving shelving partition and added stairs

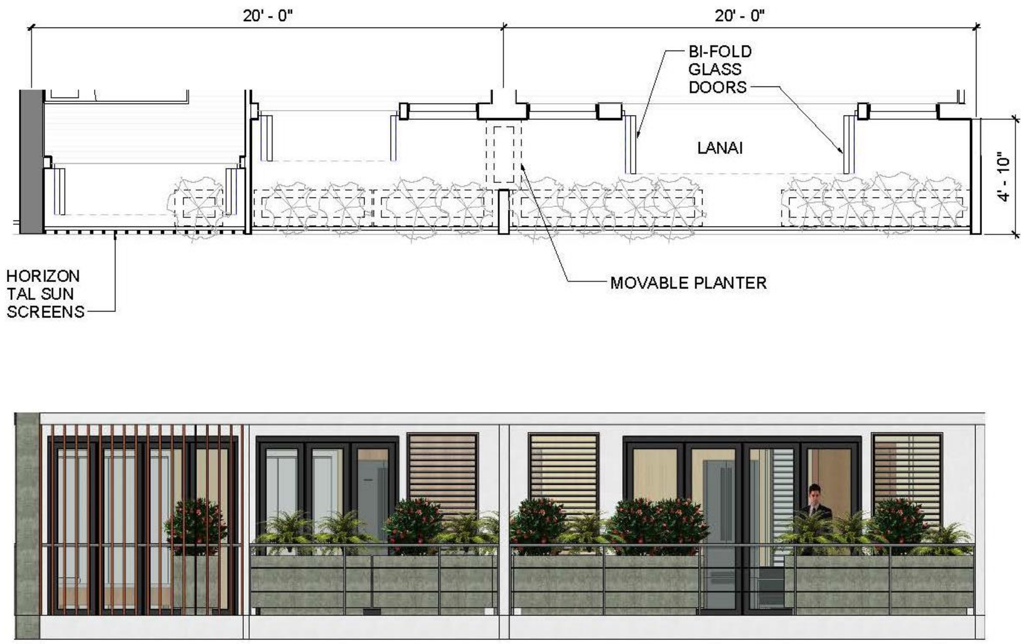


Figure 117: Unit Lanai Layout 1&2

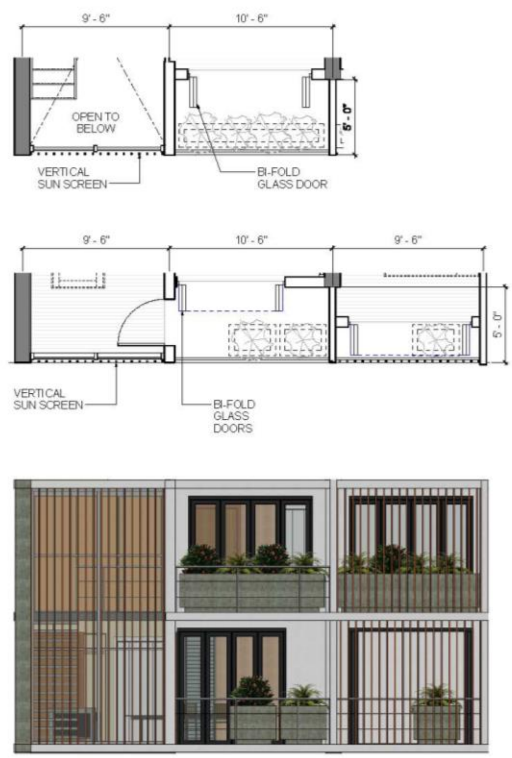


Figure 118: Unit Lanai Layout 3&4

The units designed, consists of 4 layouts; 2 configuration with different strategies of flexibility for the single floor (layout 1&2) and 2 configurations with different flexibility strategies for the the stacked layout (Layout 3&4). Each unit is able to adapt from a 2 bedroom to a 3 bedroom, 3 bedroom to 4 bedroom unit which may also be a 3 bedroom unit and a studio. The units also have lanai space at the exterior façade which offers bth a private or semi private outdoor space for gardening or lounging.

	Flexibility type	Strategy	Opperability
Layout 1	+ Horizontal Flexibility	+ Folding Wall + Movable Planters as Partitions + Connected Lanai	+ Panels on track system +Free Standing Element
Layout 2	+ Horizontal Flexibility	+ Movable Furniture partitions + Wall Folding Bed + Movable Planters as Partitions + Connected Lanai	+Free Standing Element
Layout 3	+ Vertical Flexibility	+ Folding Wall + Movable Planters as Partitions + Added Staircase	+ Panels on track system +Free Standing Element
Layout 4	+ Vertical Flexibility	+ Movable Furniture partitions + Wall Folding Bed + Added Staircase	+Free Standing Element

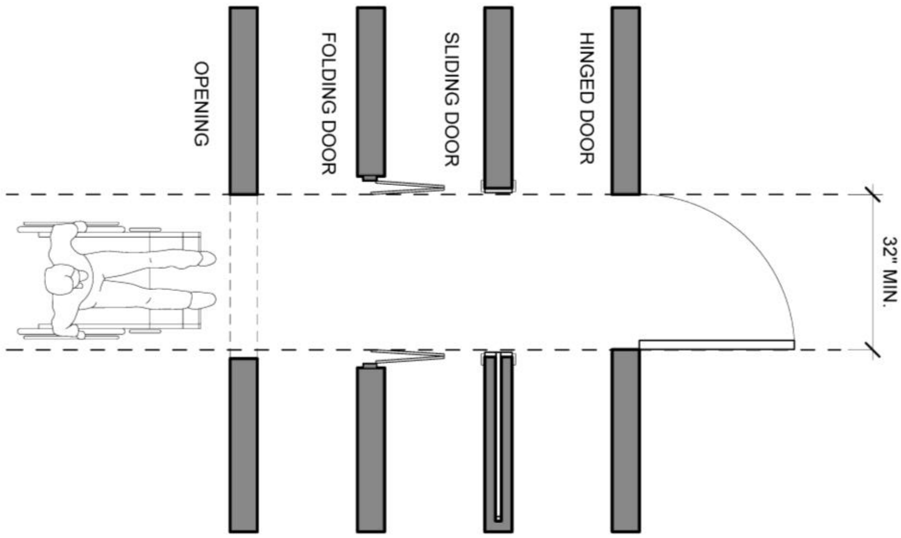


Figure 119: Doorway Minimum Width

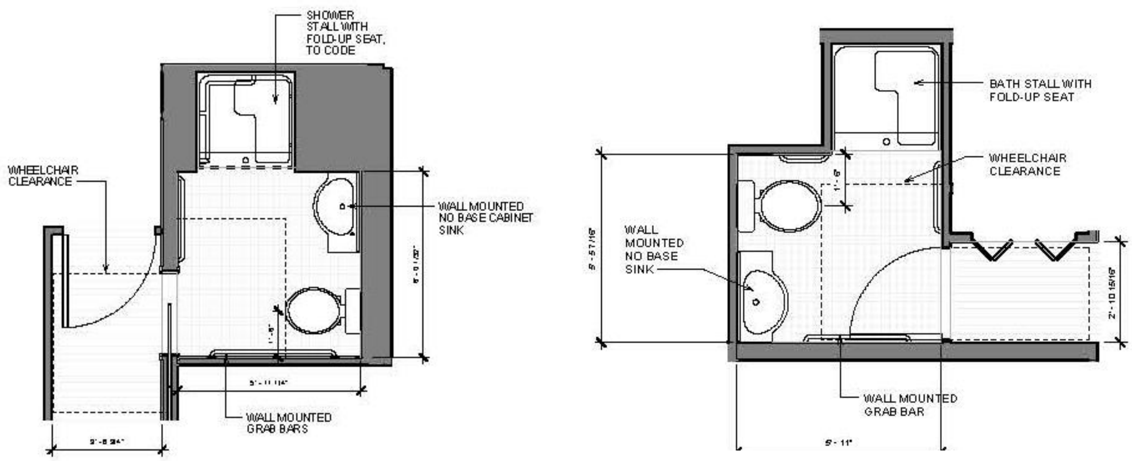


Figure 120: Bathroom Dimension for Americans with Disabilities (ADA)

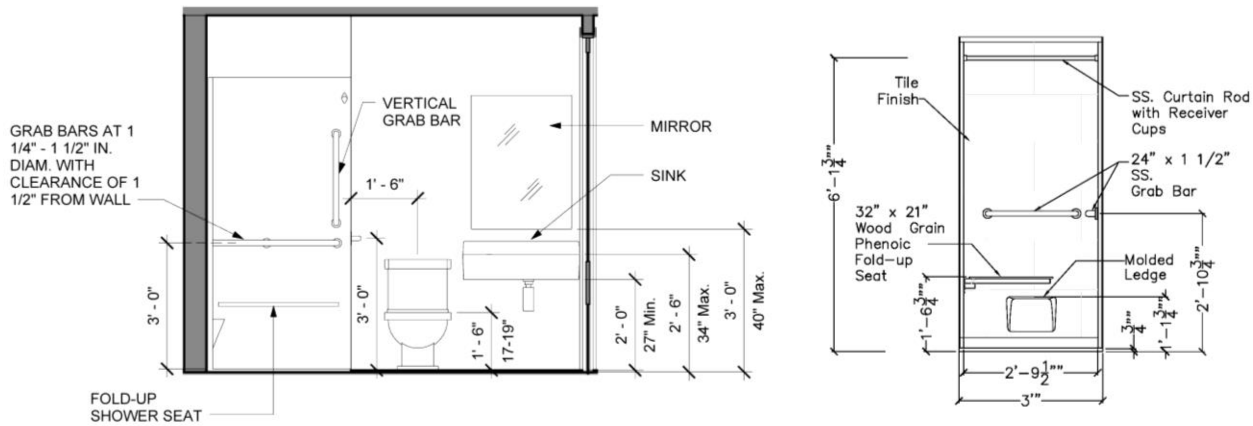


Figure 121: Bathroom Proper Dimensions

In designing the units, universal design strategies were also applied. This includes, 32 in. doorway width (Figure 119), Openings and corridor dimension requirements, bathroom dimension requirements and a ramp circulation at the sky lanai which connects the floors vertically.

Prototype 1: Layout 1A, open folding wall

Prototype 1: Layout 1B, Closed folding wall


Prototype 1: Sky Lanais

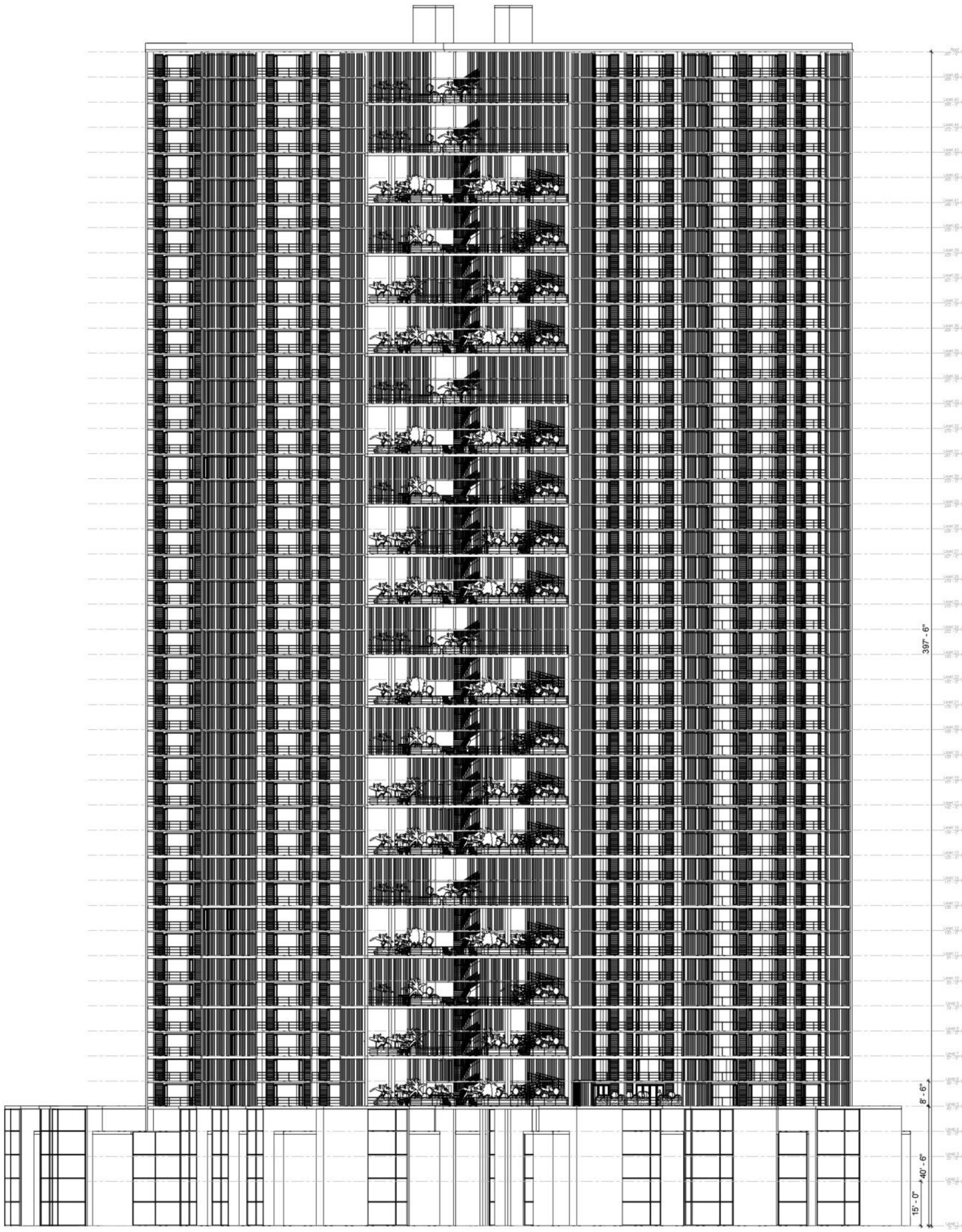
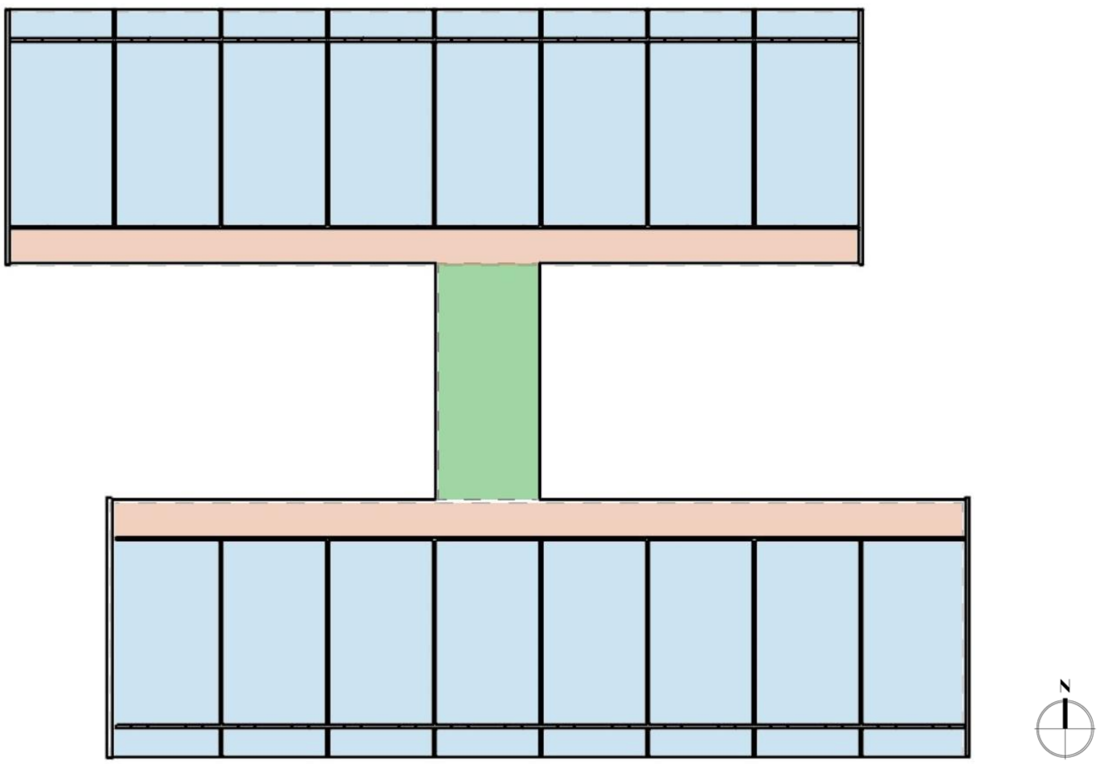
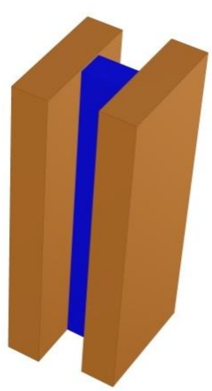


Figure 122: Prototype 1 South-West Elevation

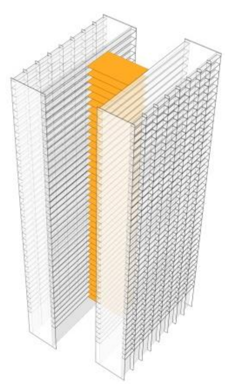
17.4 Prototype 2

Massing

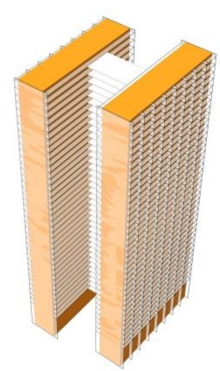




Mass Composition



Central Circulation & Sky Lanais



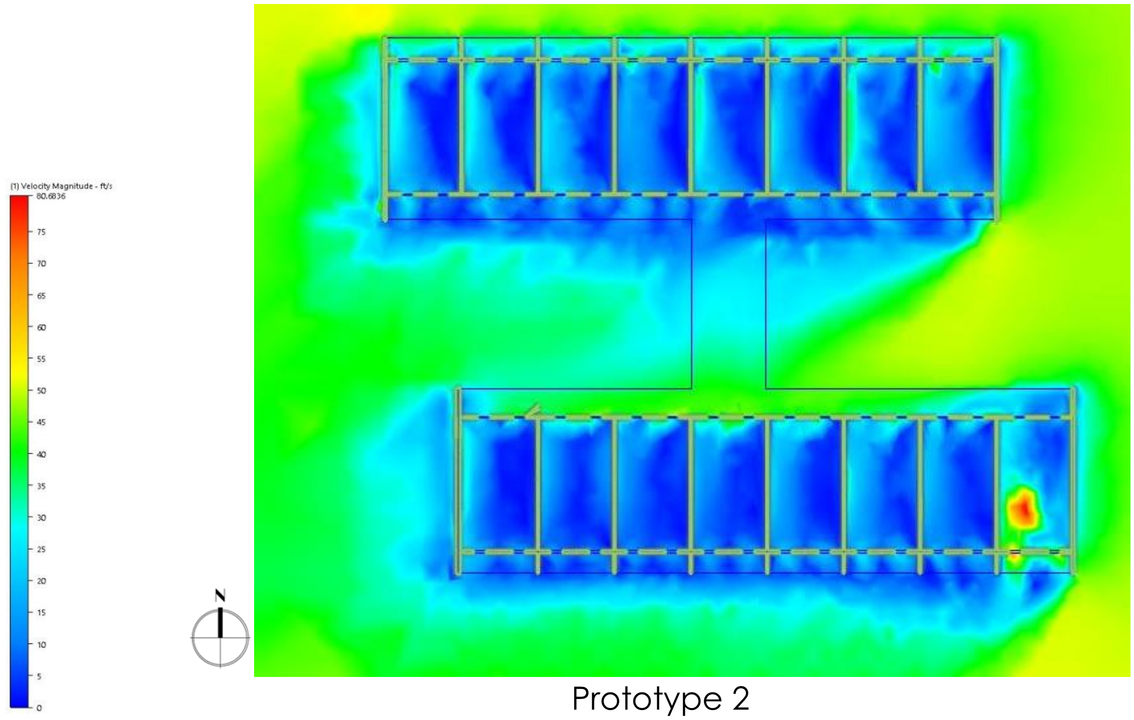
Units

The goal for prototype 2 is optimization of the design for performance, therefore when looking back at the previous direct solar exposure of simple massing (Figure 106); the south oriented mass displayed a more effective orientation. In addition, the wind flow analysis of the simple masses (Figure 107, Figure 108) implies that the south orientated building offers a higher opportunity for cross ventilation. Further investigation is conducted in the following section.

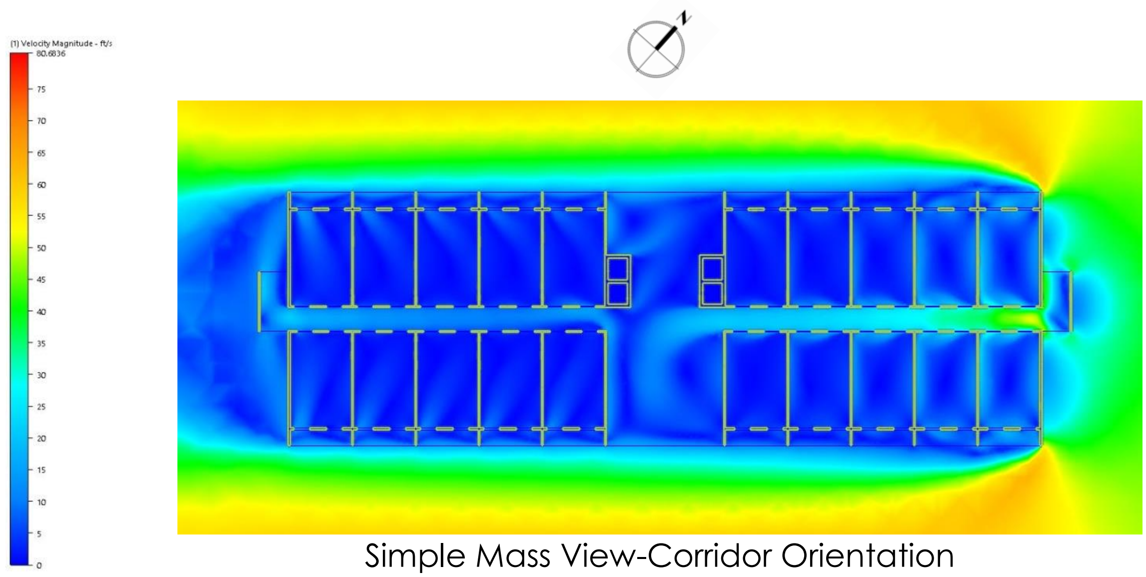
Prototype 2 consists of two south-oriented volumes with single loaded corridors that connect to a central circulation. The building mass for this prototype is slimmer and longer in plan, and thus the units have deeper layouts consisting of façades that are exposed at each end which improves cross ventilation and daylighting which is further investigated in the following section. The building also consists of shading devices which are analyzed in the later section.

Natural Ventilation

The orientation of the building mass as assessed in the previous section determined that the south oriented building mass displayed more opportunity for cross ventilation. To further assess this, CFD simulation is conducted.



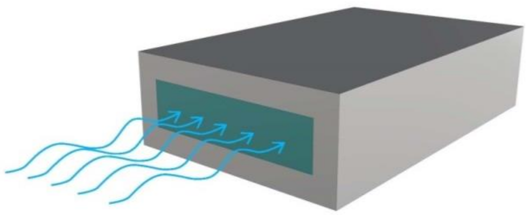
Prototype 2

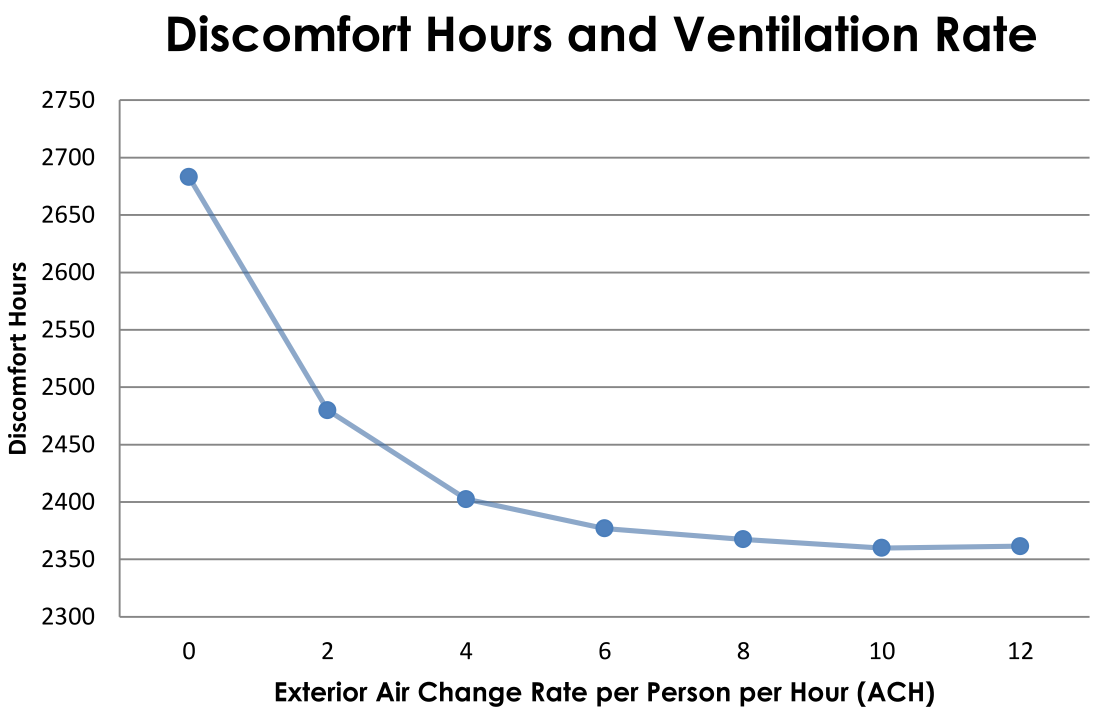


Simple Mass View-Corridor Orientation

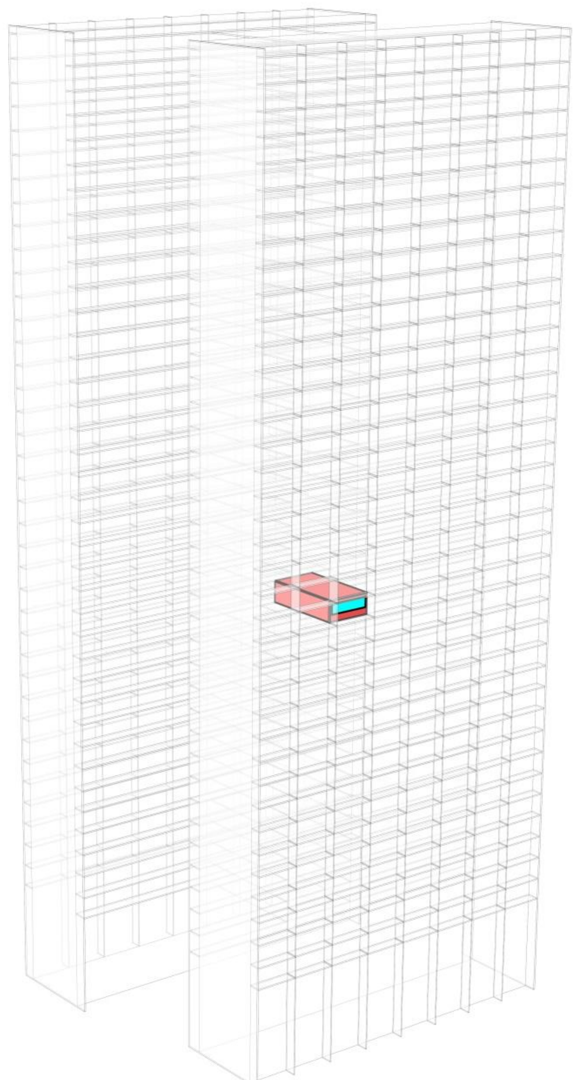
Figure 123: Prototype 2 Wind Flow Simulation

Wind flow within the building was assessed by applying simple openings onto the exterior façades. The results determine that by orienting the building mass, cross ventilation was easily improved.

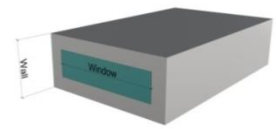



Discomfort Hours and Ventilation Rate
Discomfort Hours
2750
2700
2650
2600
2550
2500
2450
2400
2350
2300
0
2
4
6
8
10
12
Exterior Air Change Rate per Person per Hour (ACH)

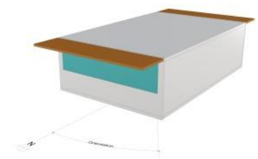
Shading Design



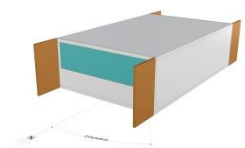
Location of Unit for Comfort Simulation



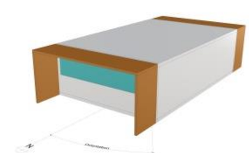
Window to Wall Ratio



Overhang Depth and Impact

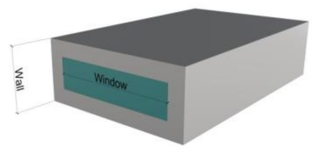


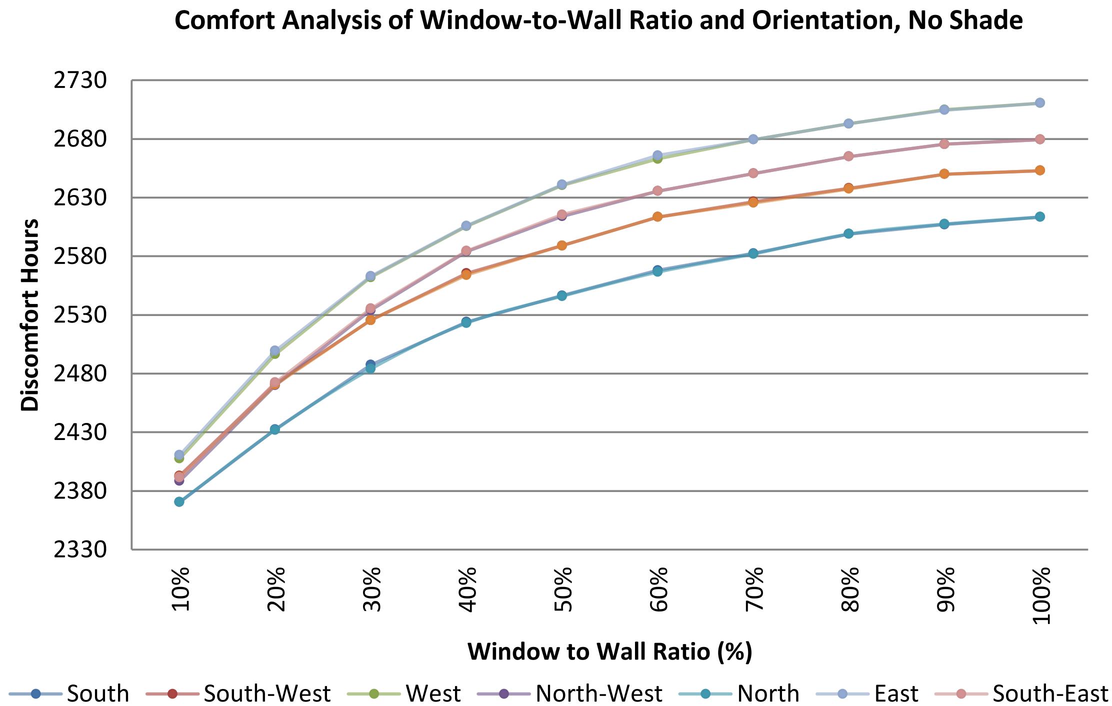
Fins Depth and Impact



Combined Shading; Depth

Impact





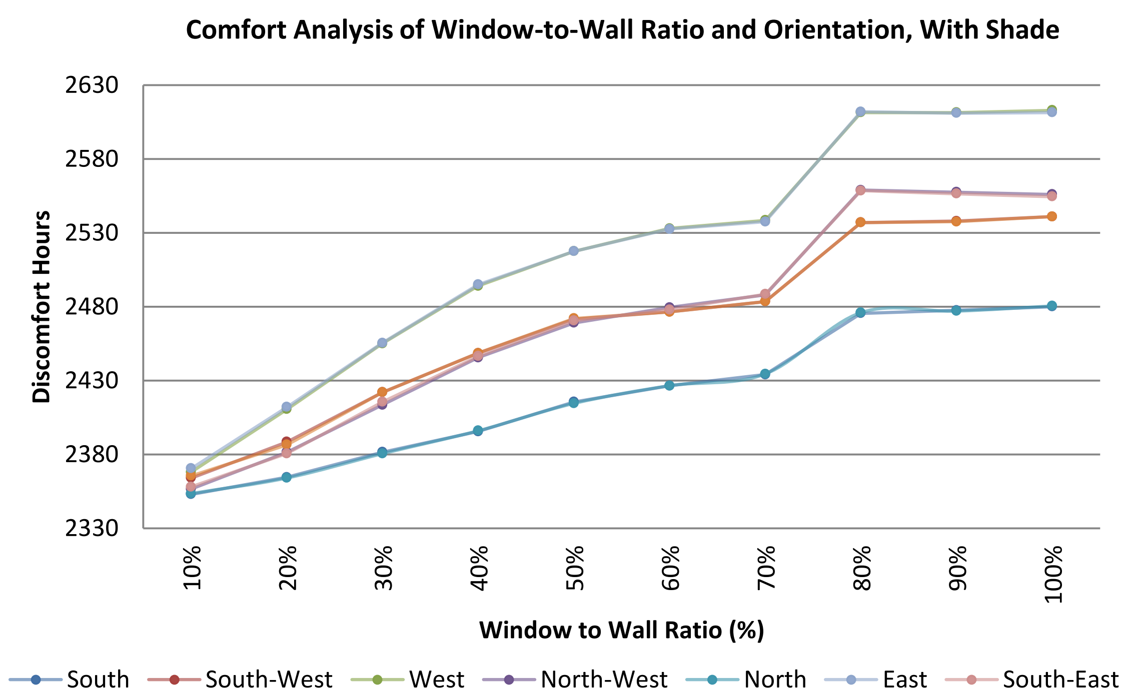
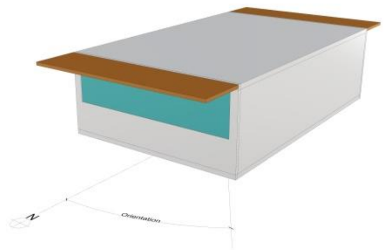
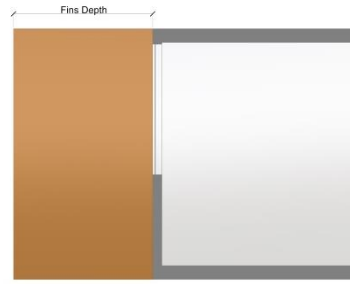


Figure 124: Window-to-Wall Ratio Comfort Analysis

The simulation of the window to wall ratio is similar to protoype 1 with a naturally ventilates unit and comparison between a unit with and without a shading device. The results are also similar, with a trend indicating that as window-to-wall ratio(%) increase, so does the discomfort hours. This is the case for both with and without shades as well as every orientation. However each orintation have significant differences in discomfort hours, with the south, south-east, east, south west and the West orientation having the larger discomfort hours in relation to the window-to-wall ratio followed by North-East, North-West and North (Figure 124). The shaded unit like prototype 1 showed significant results, indicating that there is a large change in thermal comfort after 70% of window-to-wall ratio which helps to determine the proper window size at any orientation.





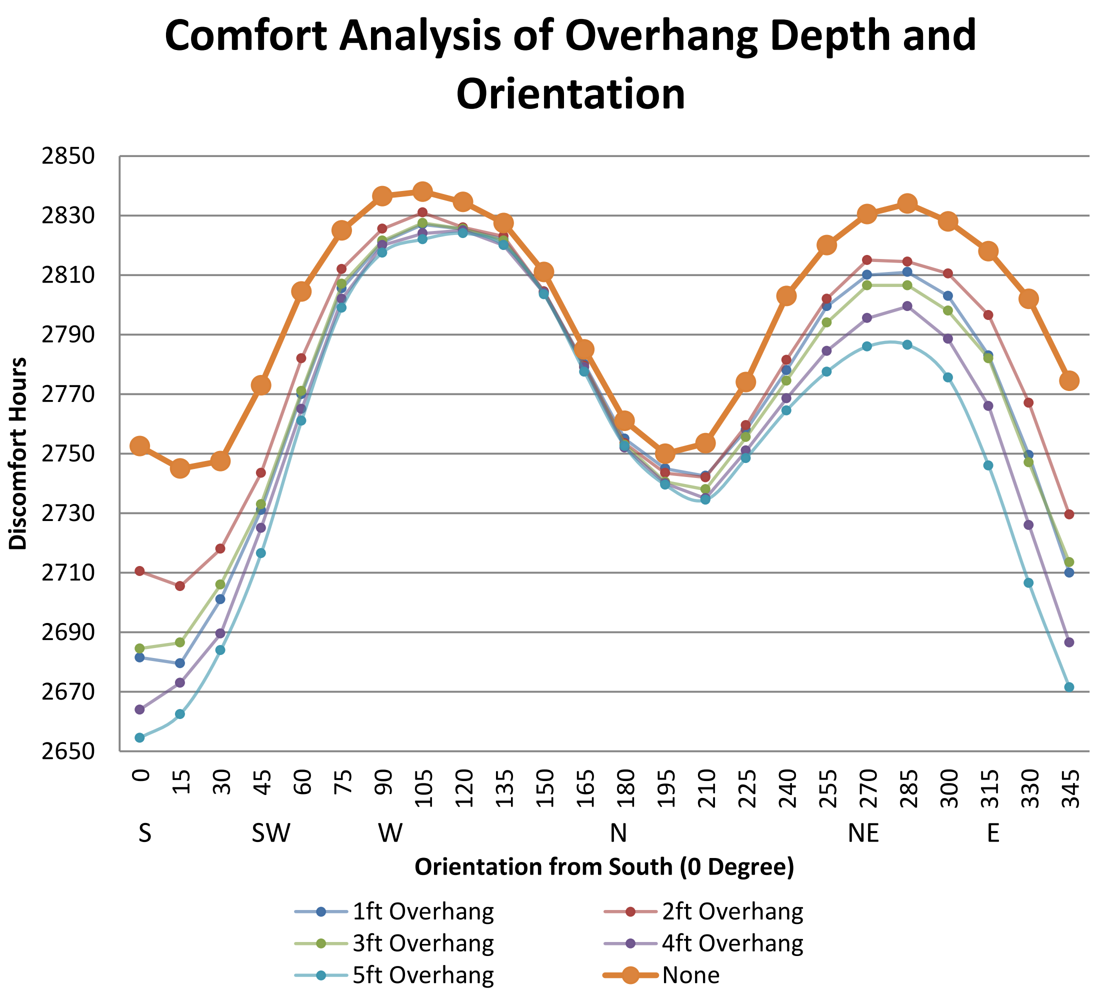
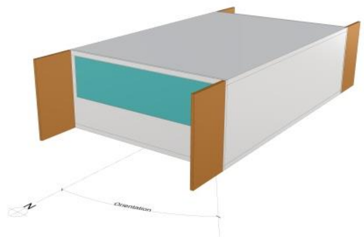
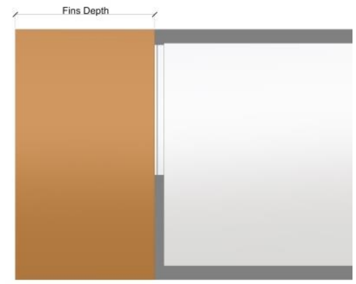


Figure 125: Horizontal Shading Device and Orientation Comfort Analysis





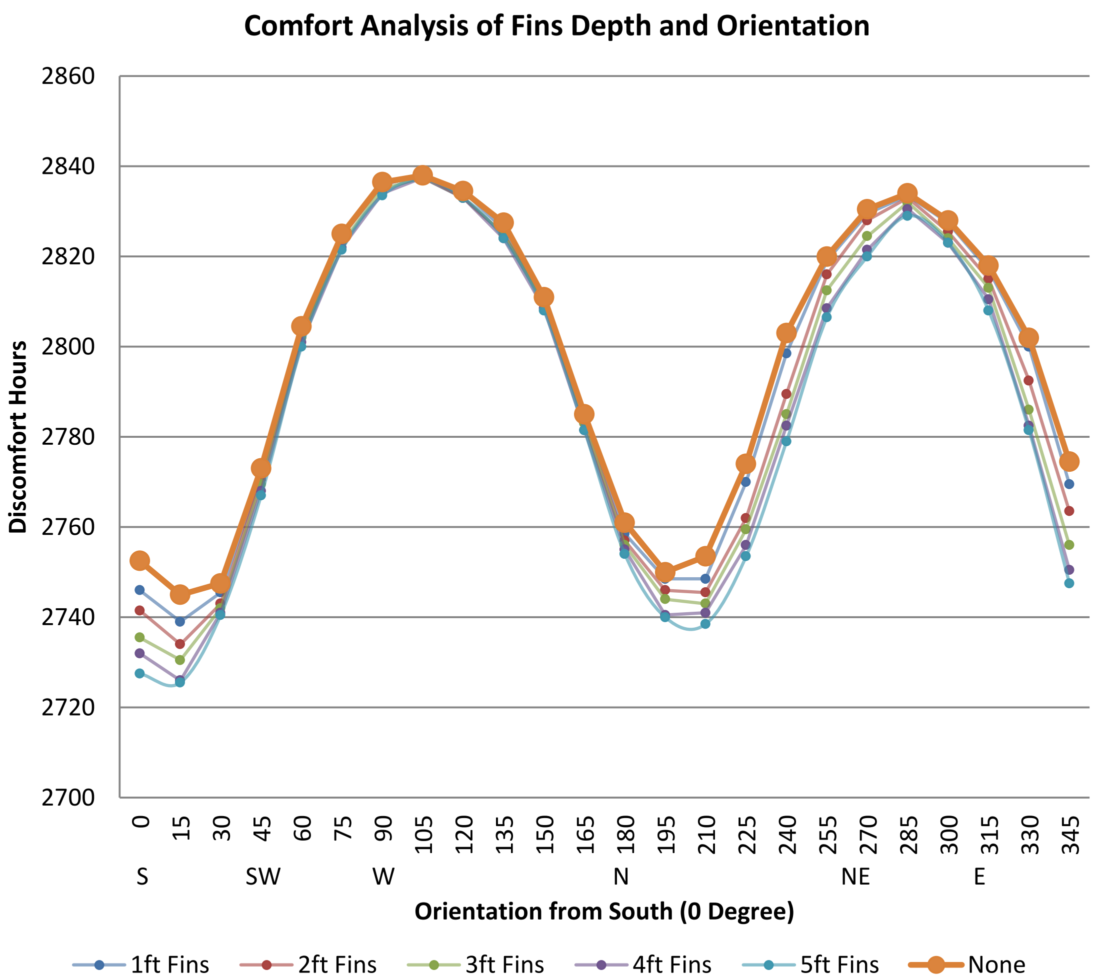
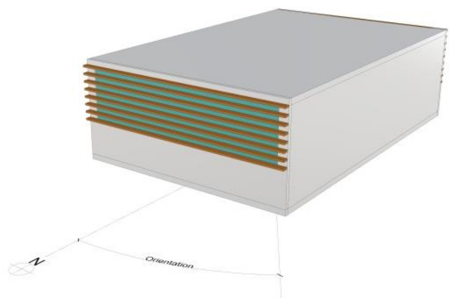
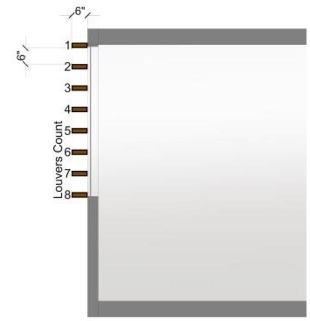


Figure 126: Fins Shading Device and Orientation Comfort Analysis





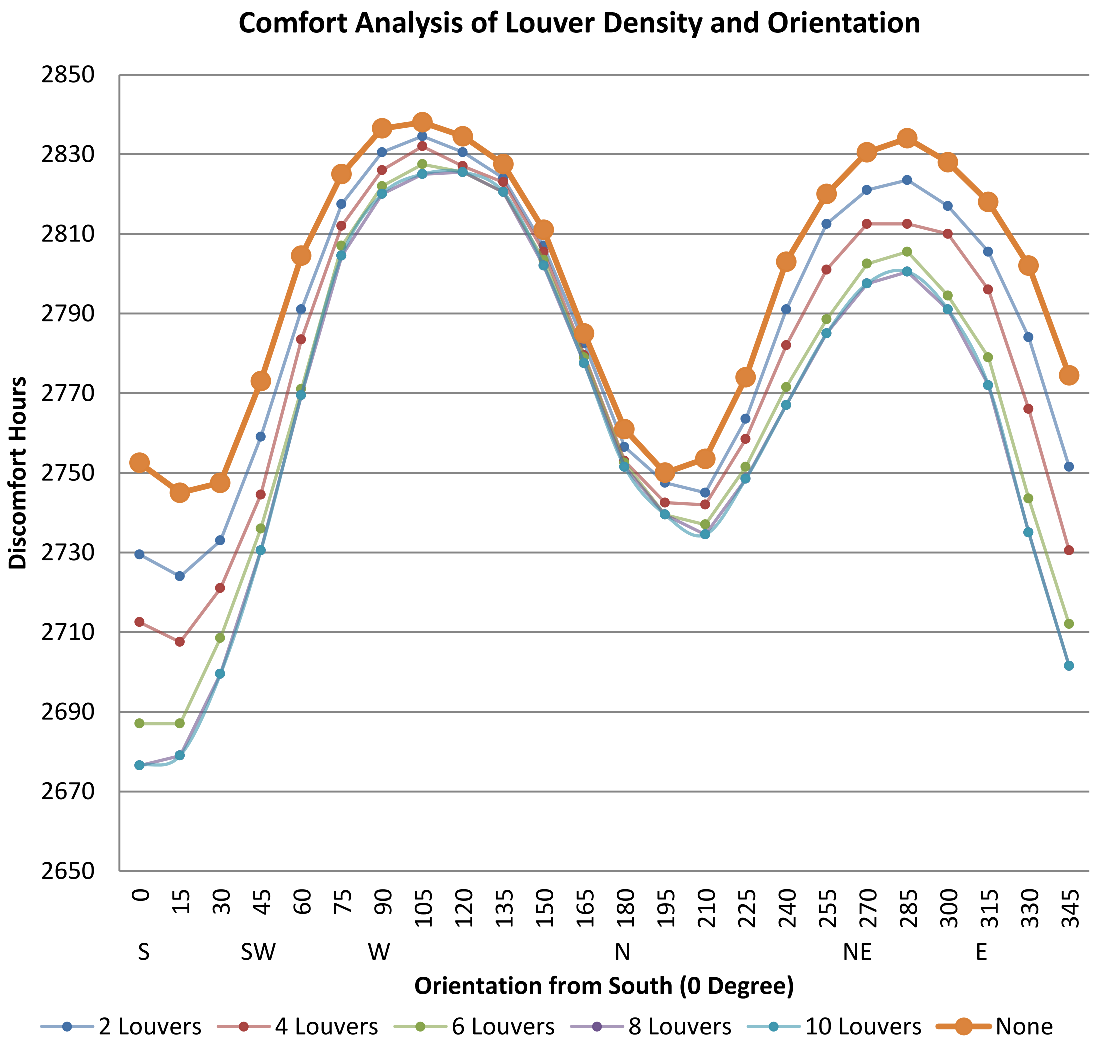


Figure 127: Louvers Shading Device and Orientation Comfort Analysis

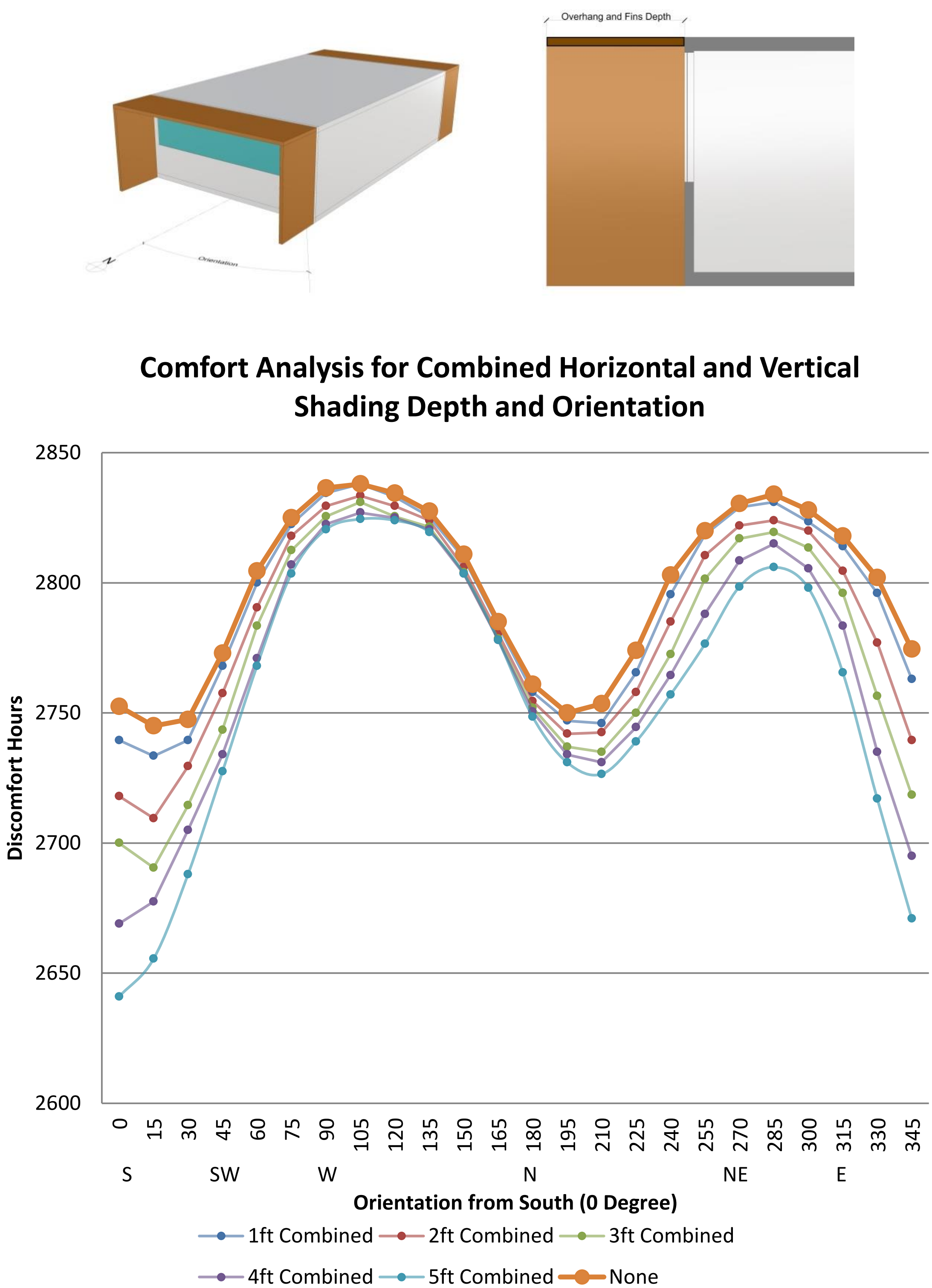


Figure 128: Combined Shading and Orientation Comfort Analysis

The parametric simulations implies that shading devices have beneficial impacts to providing thermal comfort in the indoor environment. Similar to prototype 1, the simulations show that all of the asessed shading devices improves in performance as the depth of the shade inreases.

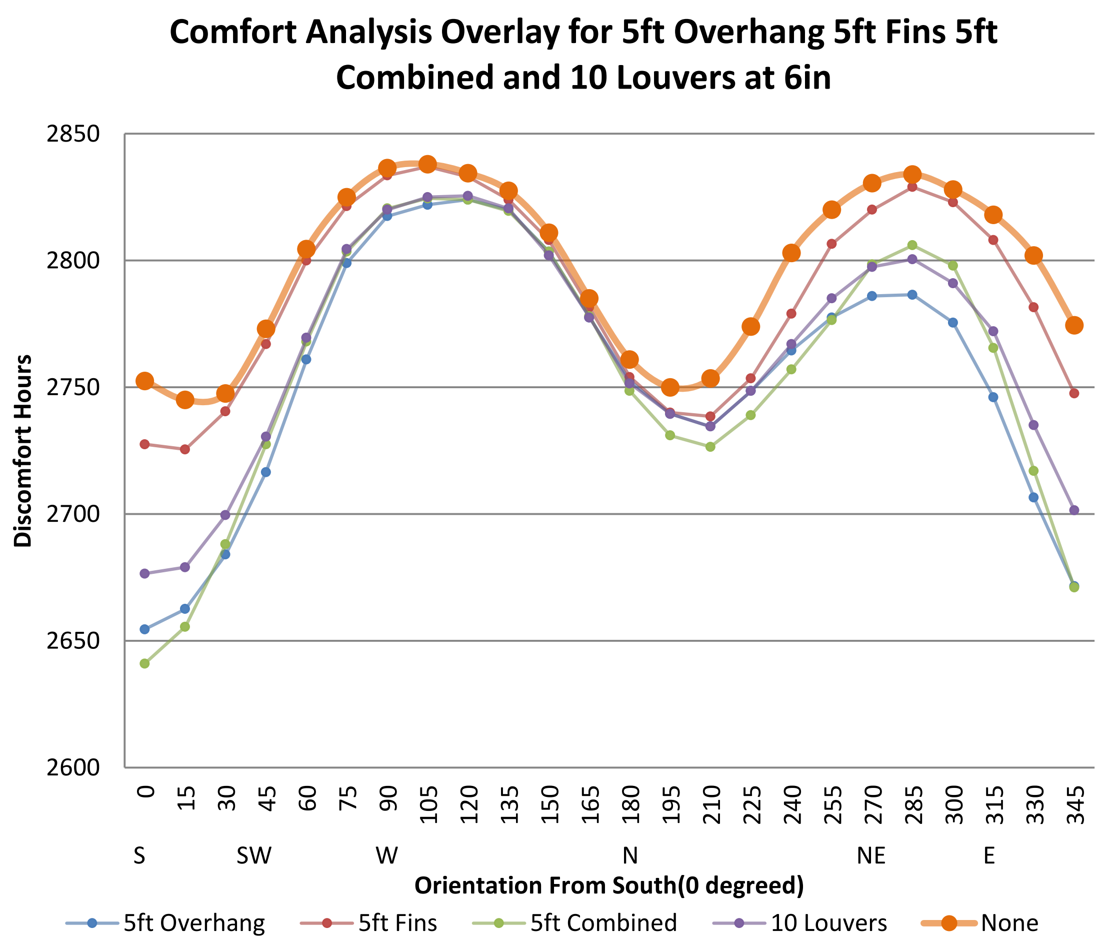
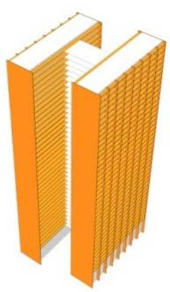


Figure 129: Comfort Analysis Overlay for 5ft Overhang, 5ft Fins, 5ft Combined, and 10 Louvers

When the shading devices are compared using the most effective depth and density(Figure 129), the 5ft overhang, 5ft combined and 10 louvers are the most effective shading device in providing comfort. The fins also show improvement in performance as depth increases, however the impact that the fins have in reducing comort is very minimal (Figure 126).

In addition to comfort analysis, direct solar radiation was also analyzed to further asess the performance of the shading device.



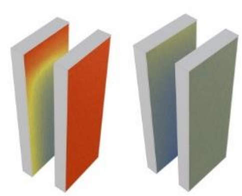
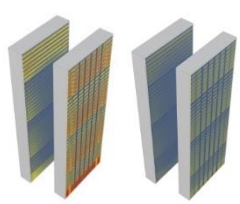
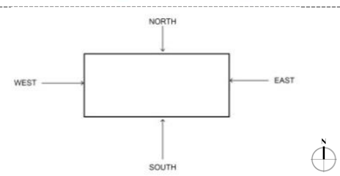
	N1 Facade **166.25** kWh/m2	S1 Facade **688.37** kWh/m2	N2 Facade **215.75** kWh/m2	S2 Facade **335.41** kWh/m2
	N1 Facade **44.99** kWh/m2	S1 Facade **233.28** kWh/m2	N2 Facade **88.38** kWh/m2	S2 Facade **90.35** kWh/m2
	**-27%**	**-34%**	**-40.9%**	**-27%**

Figure 130: Shading Device Solar Radiation Analysis

In this simulation 5ft combined shading system was used to assess the impact of shading device in reducing direct solar radiation, the results determine that the performance of the shading device is very effective; reducing direct solar radiation on all major surfaces of the building of about 30% on average. Overall the most effective shading device for prototype 2 includes the 5ft overhang, 5ft combined and 10 louvers.

In addition to providing shades, the overhang also functions as a lanai, which provides an outdoor environment on the façade for various functions such as gardening or for viewing, and potentially as an adaptive strategy.

Vertical Programming Zones

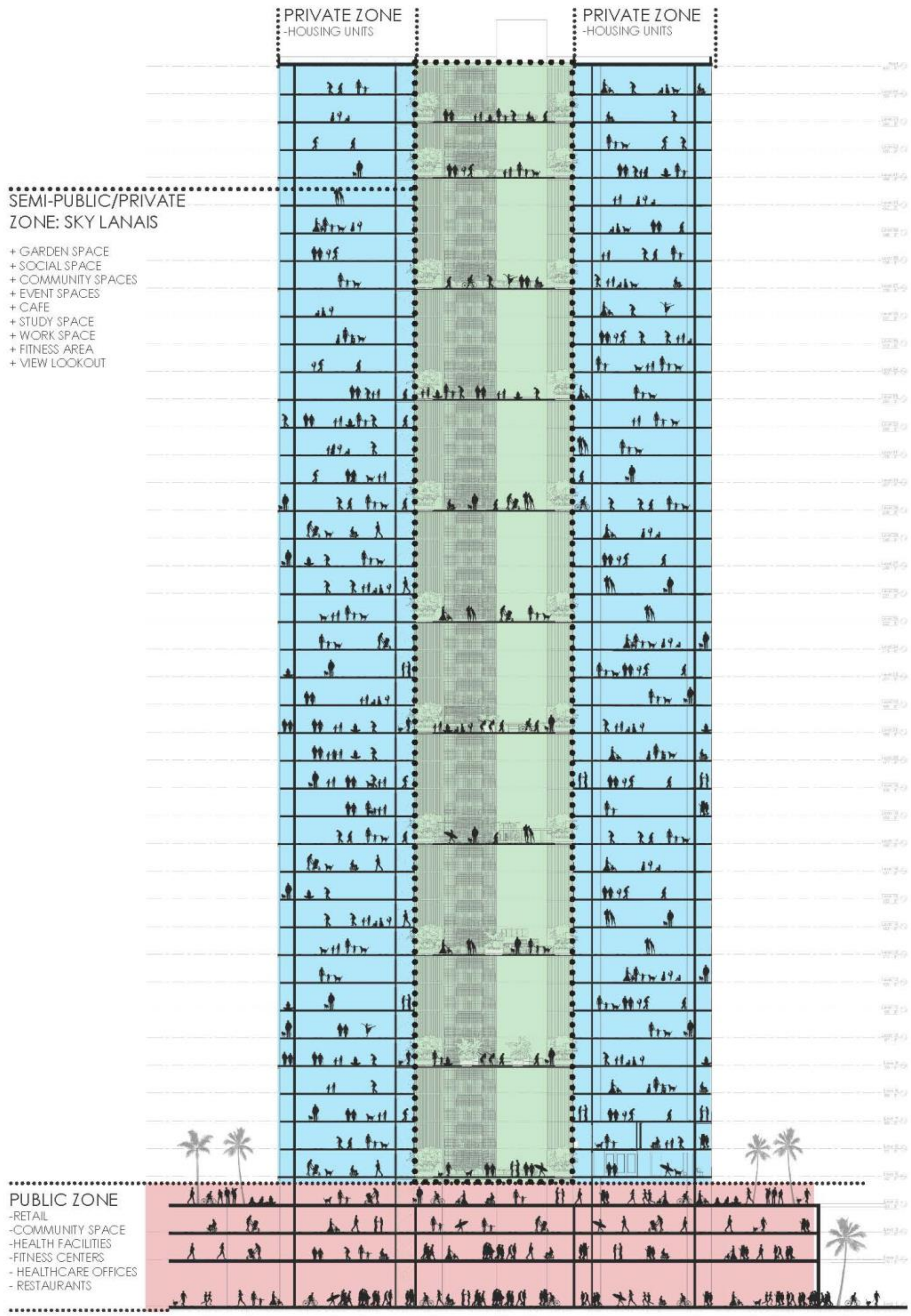
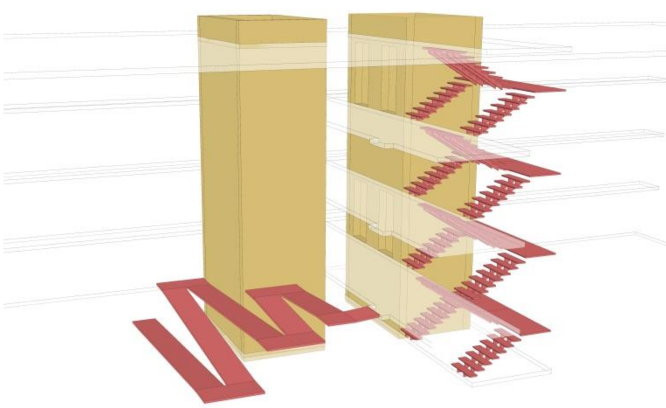


Figure 131: Building Section and Programming

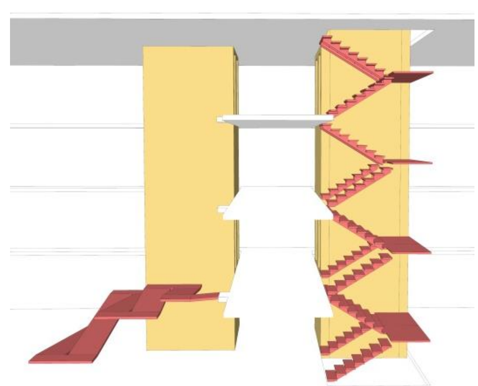
Lanai spaces are prominent throughout the building design such as the sky lanais which are community spaces with diverse functions that are incorporated into the building to promote a sense of community as illustrated in the building program (Figure 131).

The program for the high-rise residential is similar to prototype 1 which is the mixed-used building that is essential to promoting social inclusion. The programming aims to provide both private and public spaces with the lower levels being the public zone and the upper levels having both private and semi-private and public spaces. The units are strictly private while the sky lanai's function as community spaces that also allow the public to enter.

Sky Lanais and the Skip-Stop Circulation



Skip-stop circulation system



Skip-stop circulation with the Sky Lanai

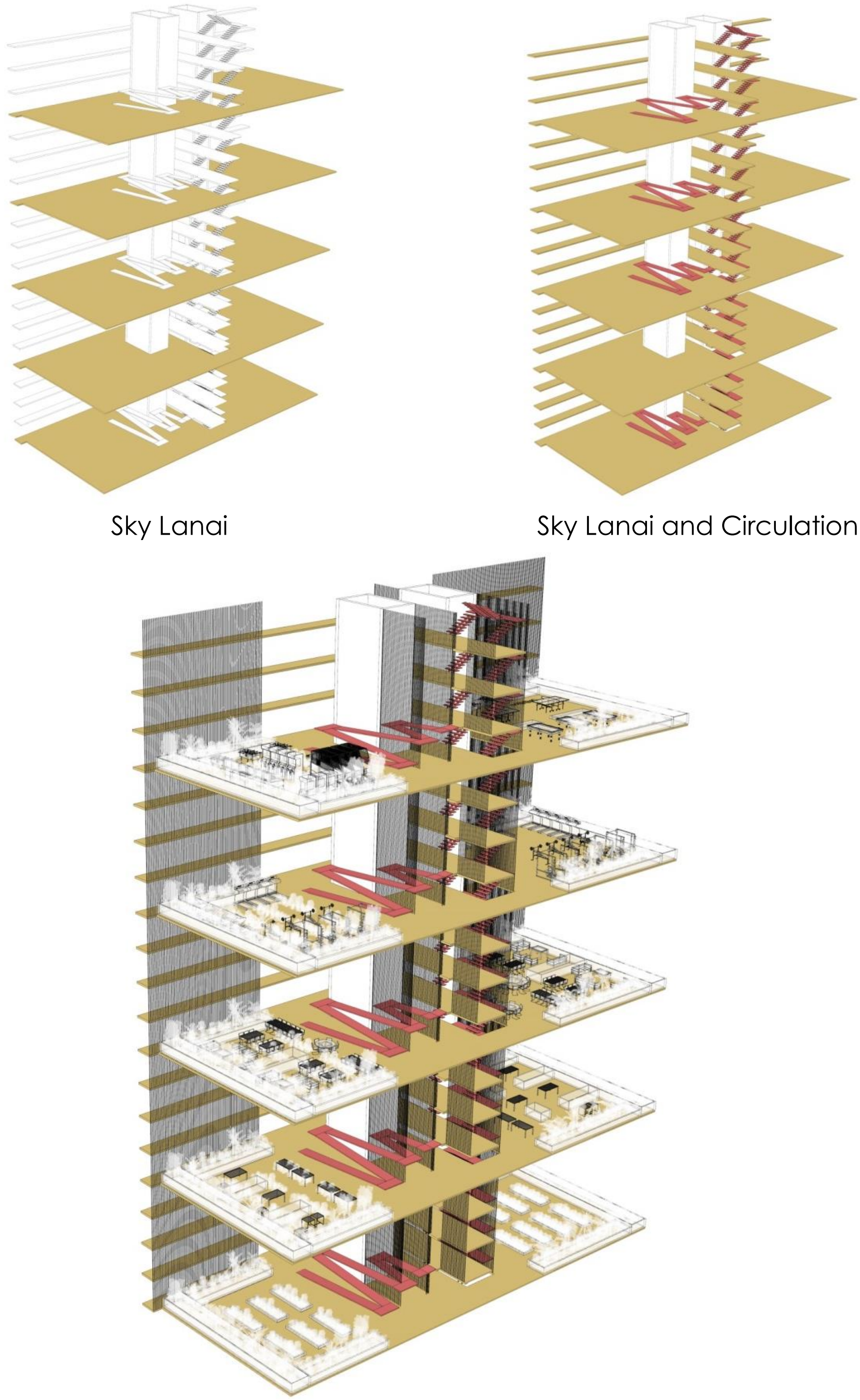


Figure 132: Prototype 2, Skip-stop Circulation and Sky Lanais

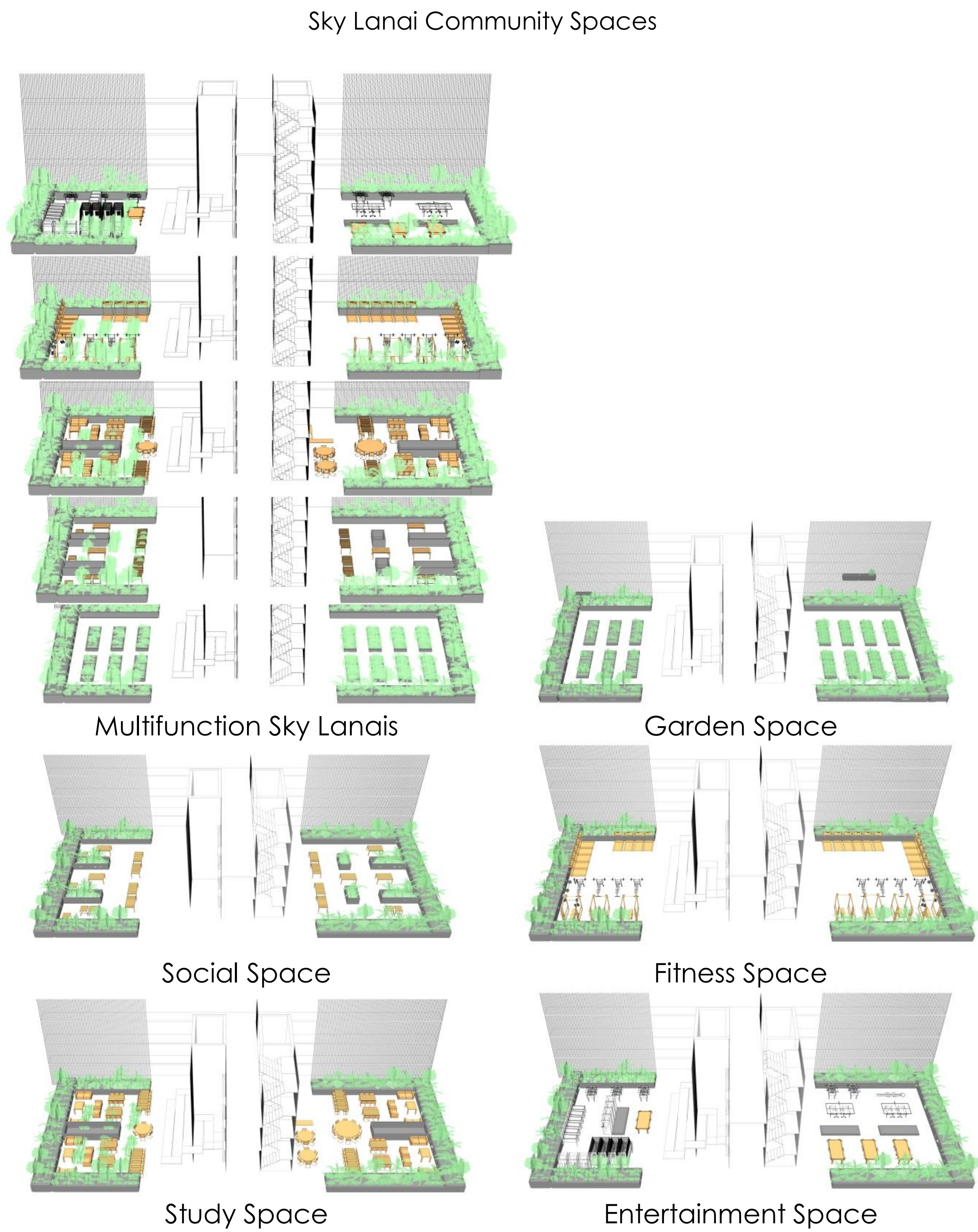
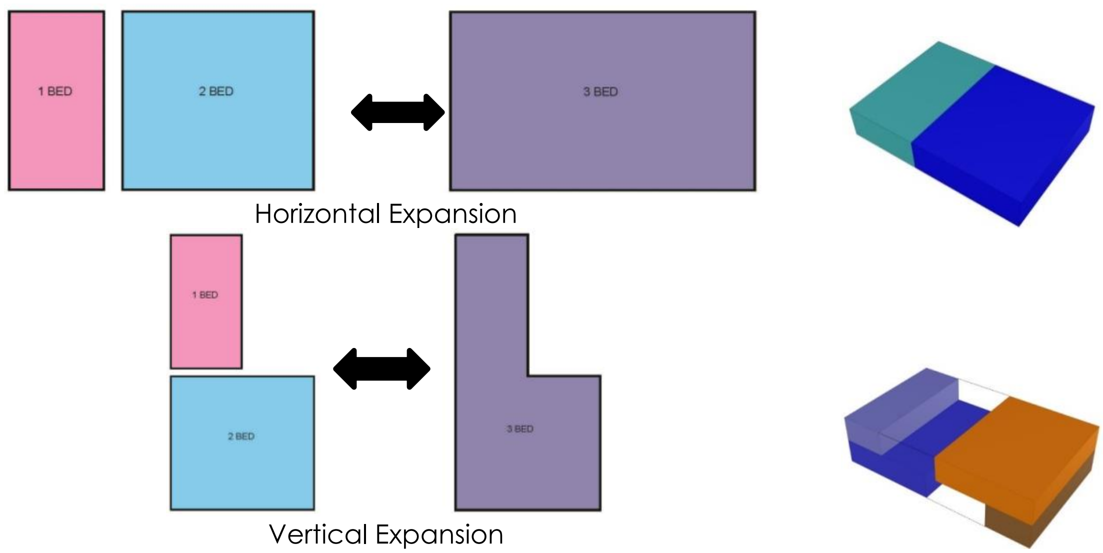


Figure 133: Sky Lanai, Community Spaces

Aside from the public zone which brings public interaction, the sky lanai is an important component of the building that enhances the social life for the occupants by providing community spaces. The sky lanais allows for various types of programs that are essential to the occupants such as gardening, lounge, fitness, or a café with study and work area, all of which accommodates the needs of the residents.

Unit Layouts



Similar to Prototype 1, the objective in designing the units for prototype 2 is to create an environment that allows the occupants to adapt the units to the changes and transformation of a family (Table 4). Just like prototype 1, this is achieved through flexible elements in both the unit and space level. The following section will investigate various options of unit layouts that offer a level flexibility to adapt for the different transformation of families.

Layout 1 & 2: Spatial Flexibility and Scenarios

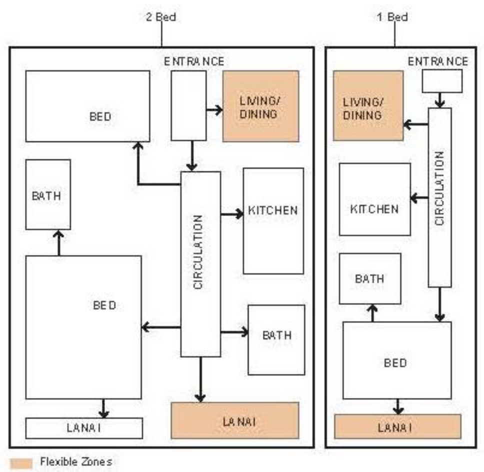
Layout 1 & 2

Couple | Nuclear

Single Parent | Single with Extended

Widowed Senior | Single Parent with older Child

Spatial Configuration: 1 Bed Unit + 2 Bed Unit



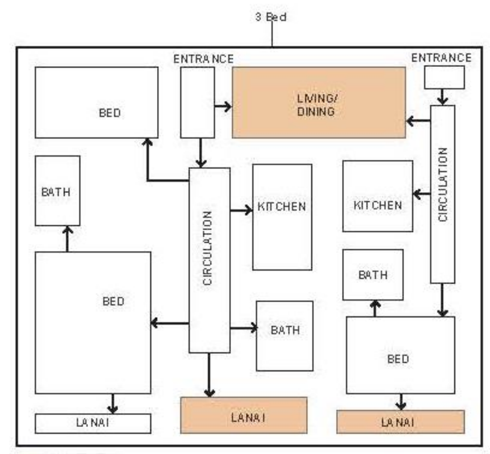
Syntax Diagram

Layout 1 & 2

Multigenerational

Single Parent + Older Child with Partner

Spatial Configuration: 3 Bed Unit, additional privacy



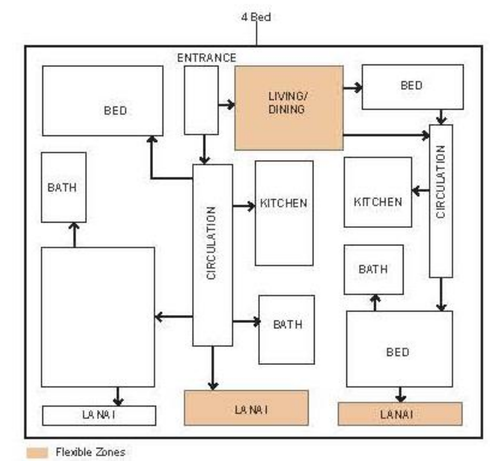
Syntax Diagram

Layout 1 & 2

Multigenerational

Multigenerational

Spatial Configuration: 3 Bed Unit



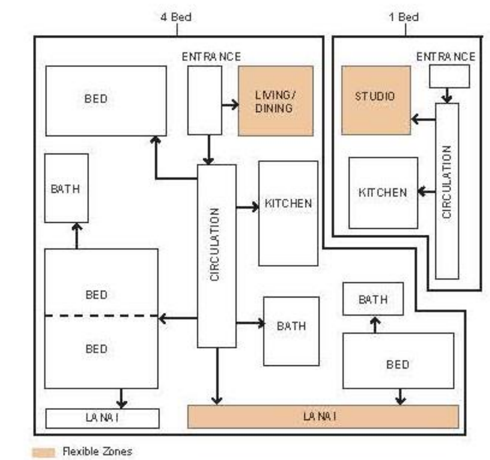
Syntax Diagram

Layout 1 & 2

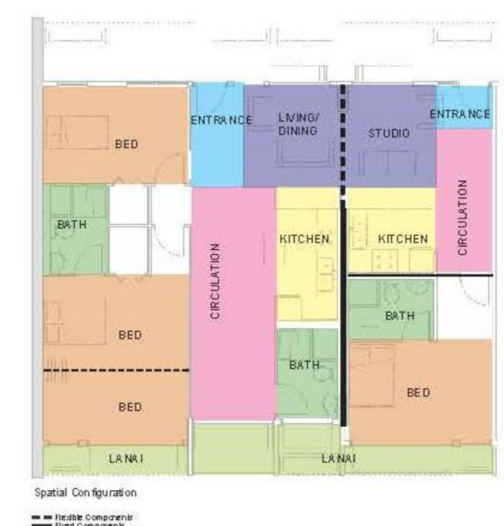
Single | Multigenerational

Single | Couple + Extended Member

Spatial Configuration: 2 Bed Unit + Studio

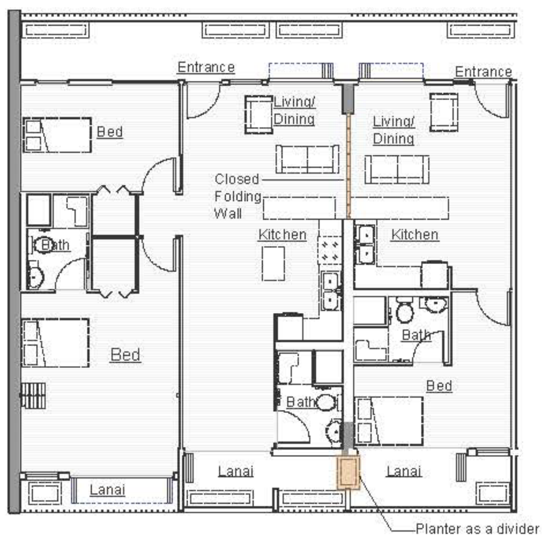


Syntax Diagram



Layout 1: Floor Plan and Flexible Components

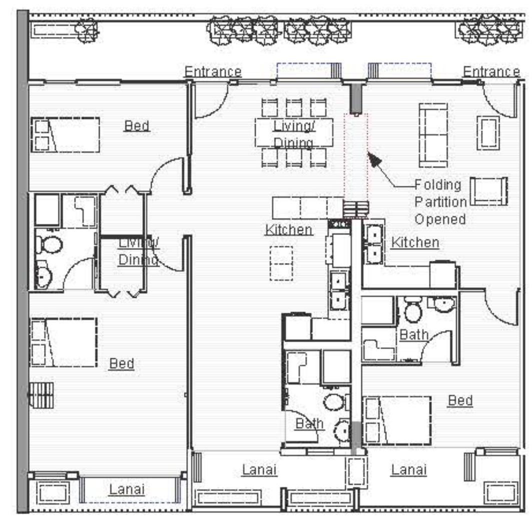
Layout 1A



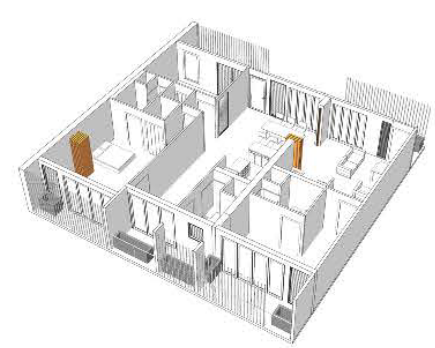
1 bed and 2 bedroom Unit

Folding partitions

Layout 1B

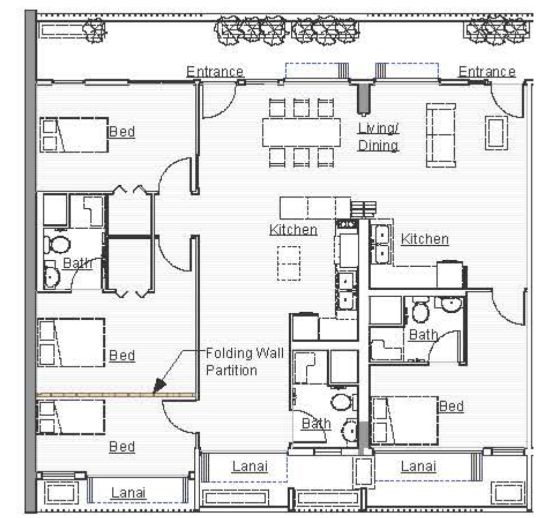


3 bedroom Unit

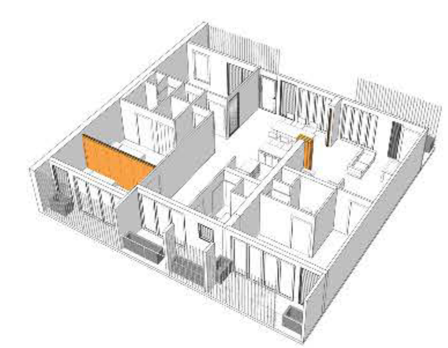


Folding partition and added stairs

Layout 1C

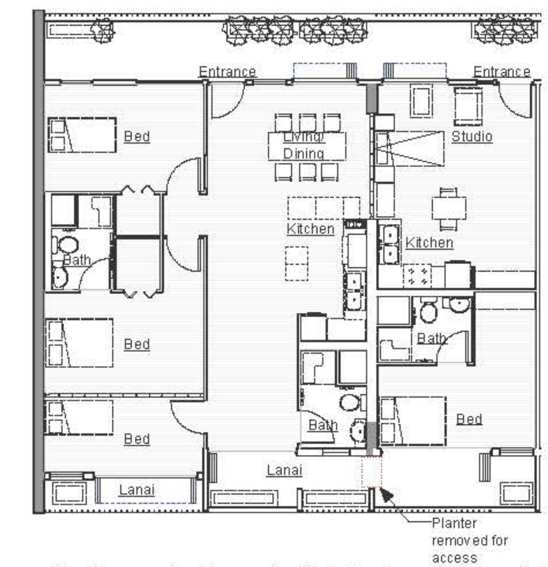


4 bedroom unit

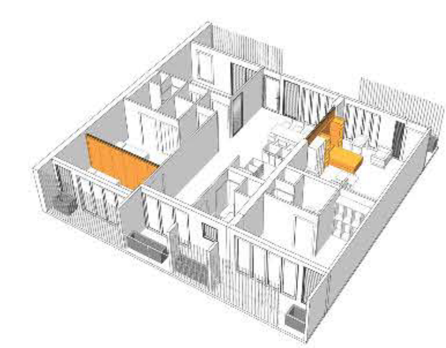


Folding Partitions and Added Stairs

Layout 1D



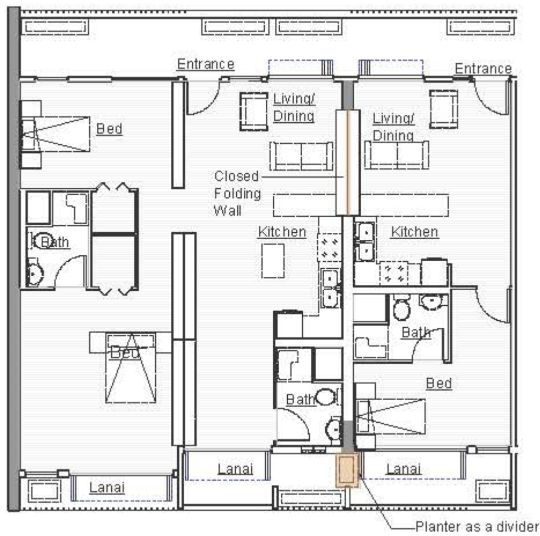
Studio created for potential single person rental



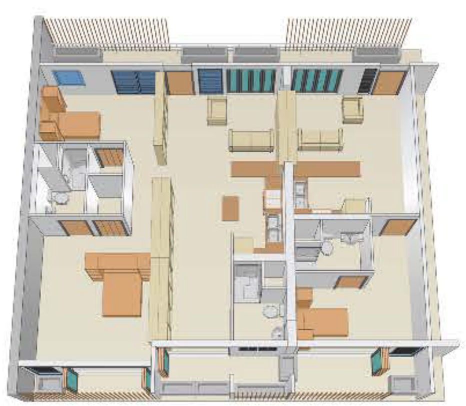
Folding Partitions and Folding Bed

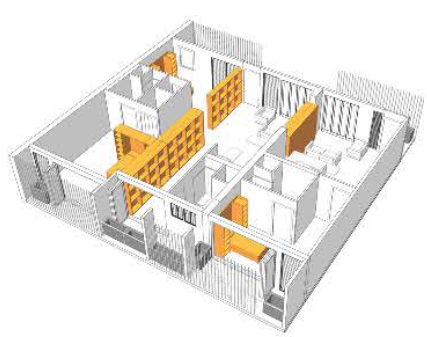
Layout 2: Floor Plan and Flexible Components

Layout 2A



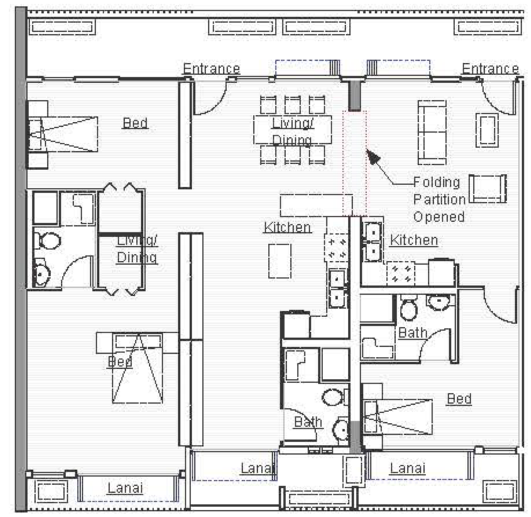
1 bed and 2 bedroom Unit



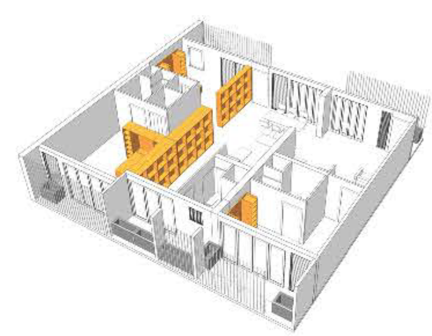


Shelf partitions and Folding Bed

Layout 2B

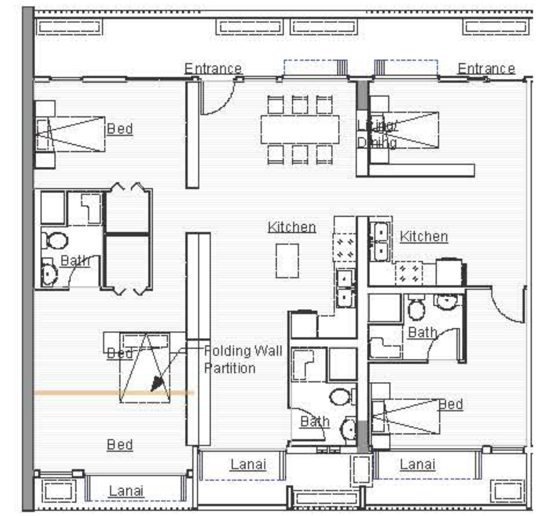


3 bedroom Unit

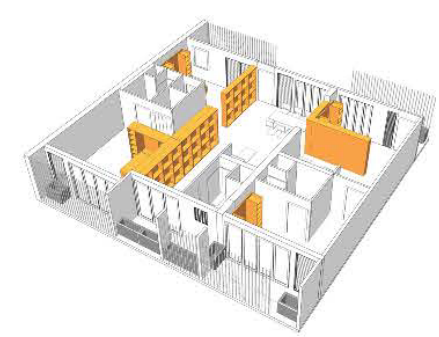


Shelf partitions and Folding Bed

Layout 2C

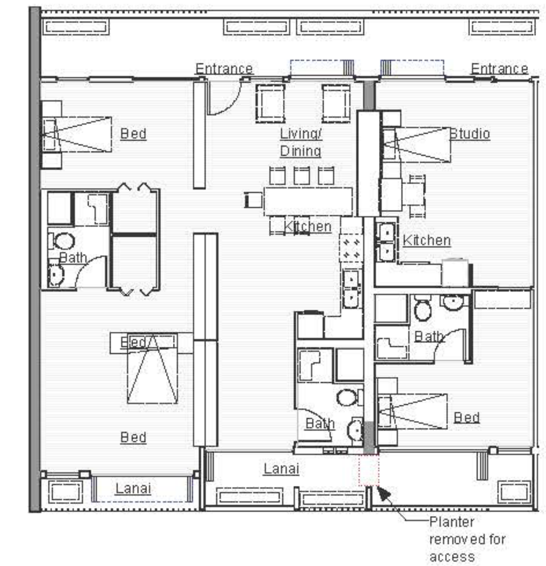


Full integration of units

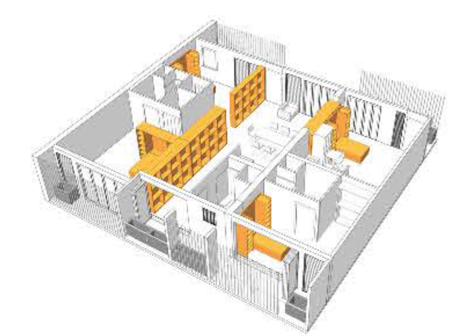


Shelf partitions and Folding Bed

Layout 2D



Studio created for potential single person rental



Shelf partitions and Folding Bed

Layout 3 & 4: Spatial Flexibility and Scenarios

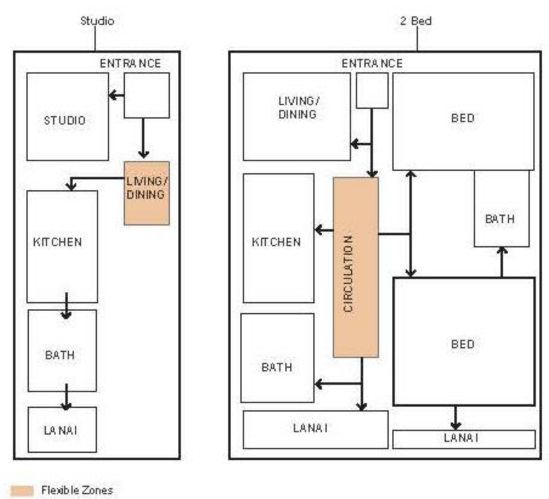
Layout 3 & 4

Couple · Nuclear

Single Parent · Single with Extended

Widowed Senior · Single Parent with older Child

Spatial Configuration: 1 Bed Unit + 2 Bed Unit

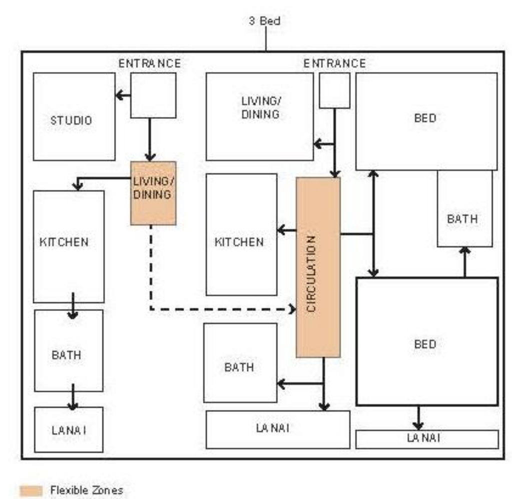


Layout 3 & 4

+ Multigenerational

Single Parent + Older Child with Partner

Spatial Configuration: 3 Bed Unit, additional privacy

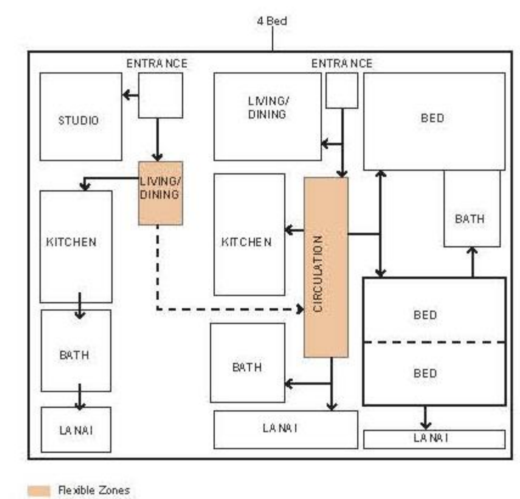


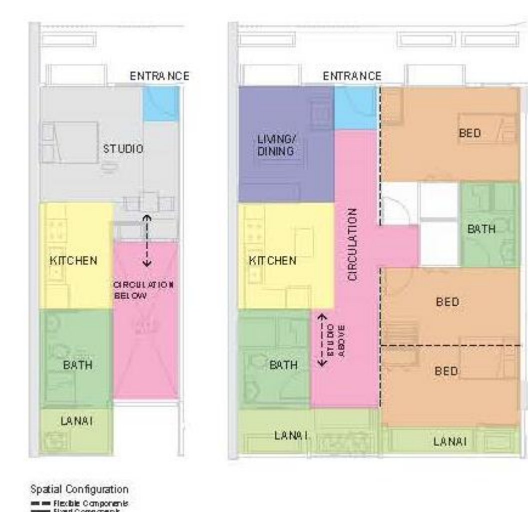
Layout 3 & 4

+ Multigenerational

+ Multigenerational

Spatial Configuration: 3 Bed Unit



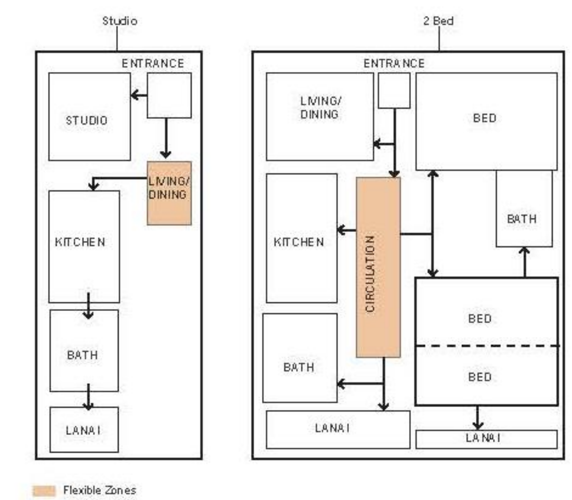


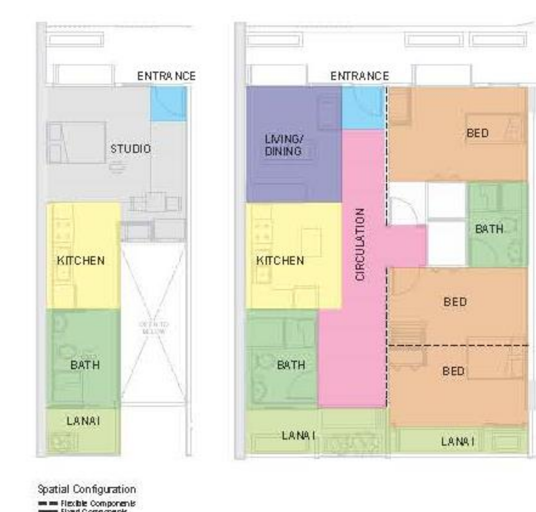
Layout 3 & 4

Single · Multigenerational

Single · Couple + Extended Member

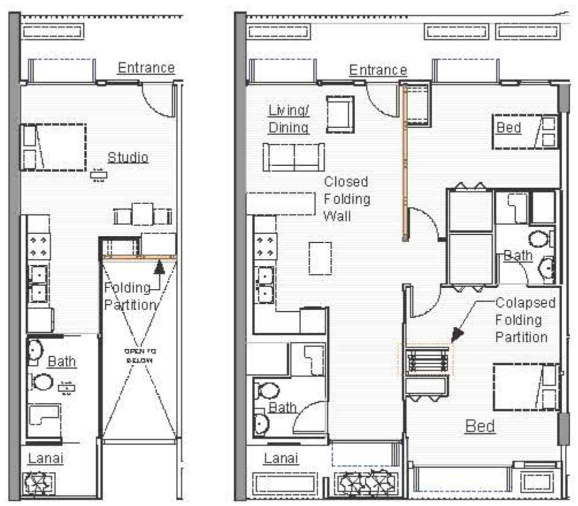
Spatial Configuration: 2 Bed Unit + Studio



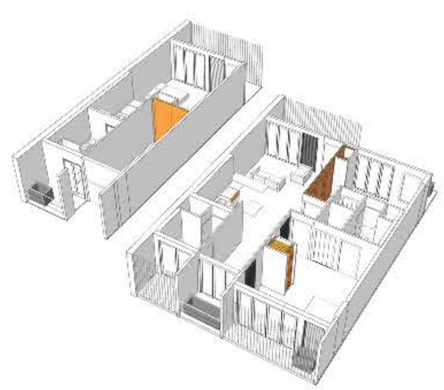


Layout 3: Floor Plan and Flexible Components

Layout 3A

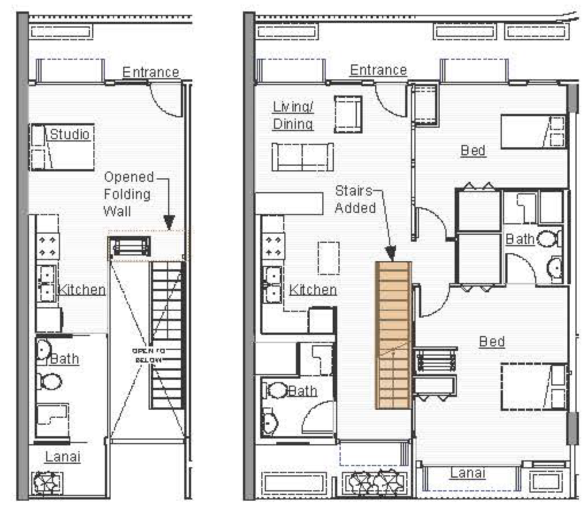


Studio and 2 bedroom Unit

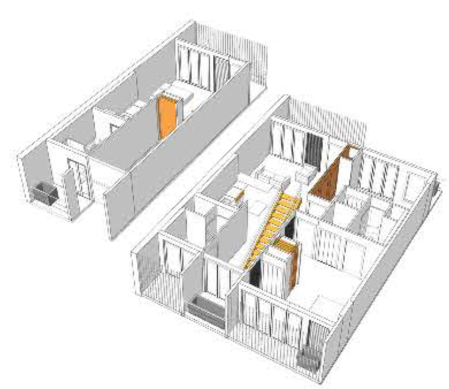


Folding partitions

Layout 3B

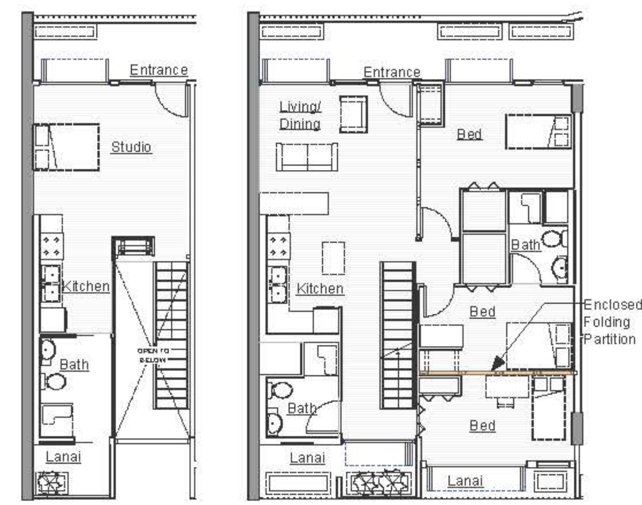


3 bedroom Unit



Folding partition and added stairs

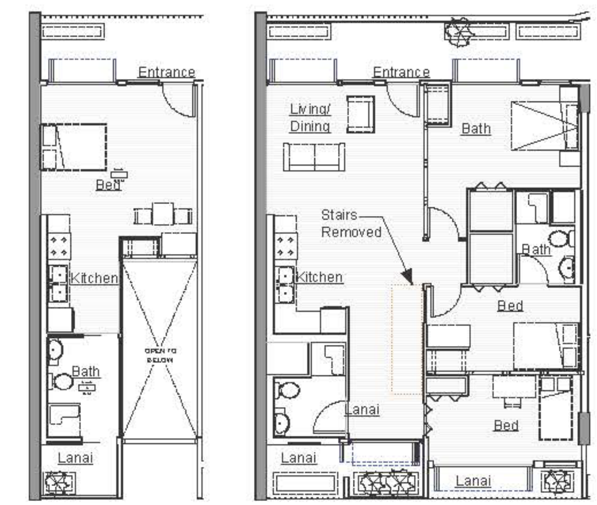
Layout 3C



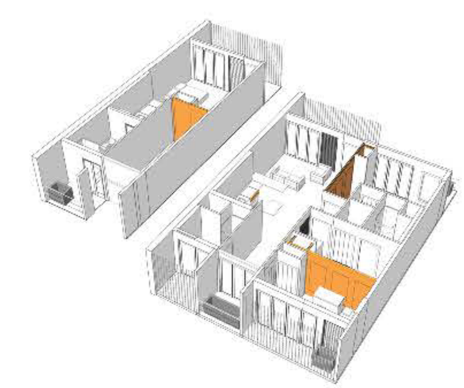
4 Bedroom

Folding Partitions and Addded Stairs

Layout 3D



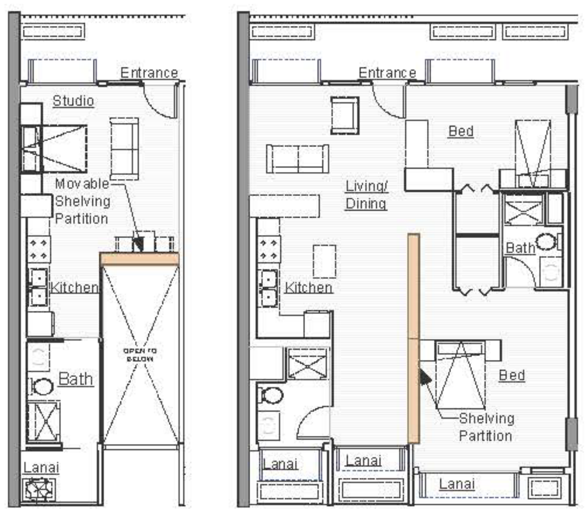
Studio created for potential single person rental



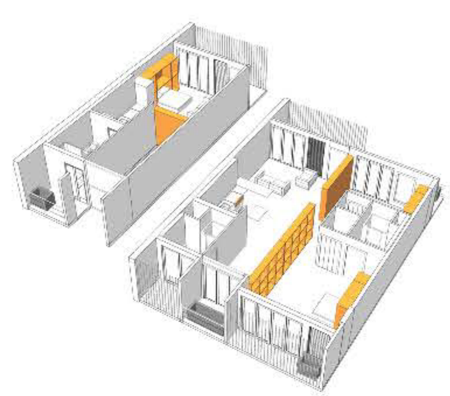
Folding Partitions

Layout 4: Floor Plan and Flexible Components

Layout 4A

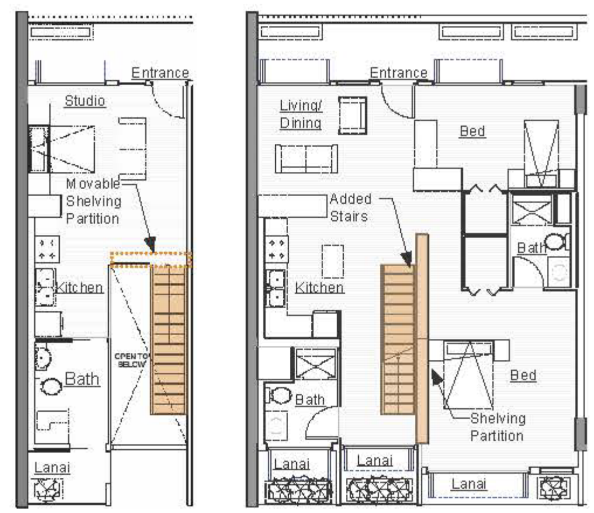


1 bed and 2 bedroom Unit

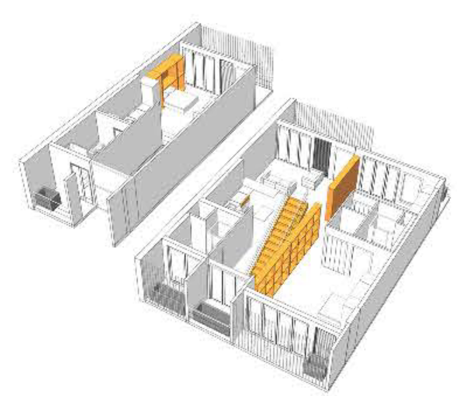


Shelf partitions

Layout 4B

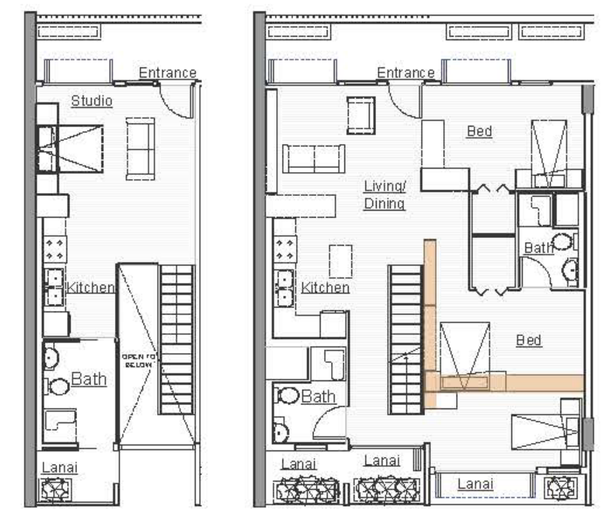


3 bedroom Unit

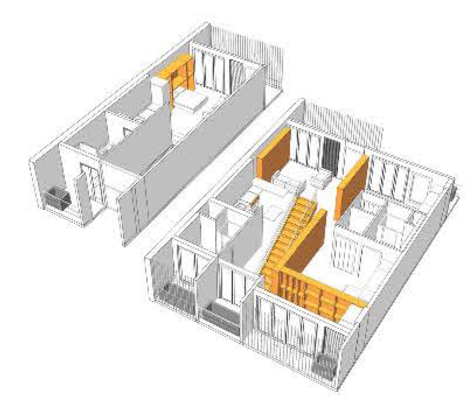


Shelf partition and added stairs

Layout 4C

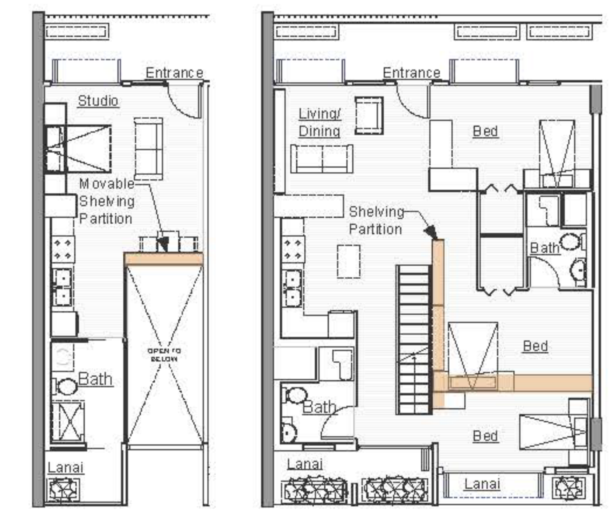


4 Bedroom

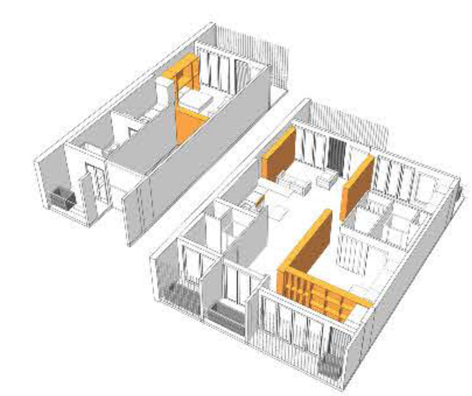


Shelf Partitions and Addded Stairs

Layout 4D



Studio and 3 Bedroom



Shelf Partitions

Figure 134: Layout 1&2 Unit Lanai

Figure 135: Unit 3&4 Unit Lanai

The units designed for prototype 2 consists of 4 different layouts; 2 configuration of which are single floor (layout 1&2) and 2 configurations that are stacked layout (Layout 3&4). Each unit is able to adapt from a 2 bedroom to a 3 bedroom, 3 bedroom to 4 bedroom, and also a unit with 3 bedroom and a studio. The units also have lanai space at the exterior façade which offers both a private or semi private outdoor space used for gardening or lounging.

	Flexibility type	**Strategy**	**Opperability**
Layout 1	+ Horizontal Flexibility	+ Folding Wall + Movable Planters as Partitions + Connected Lanai	+ Panels on track system +Free Standing Element
Layout 2	+ Horizontal Flexibility	+ Movable Furniture partitions + Wall Folding Bed + Movable Planters as Partitions + Connected Lanai	+Free Standing Element
Layout 3	+ Vertical Flexibility	+ Folding Wall + Movable Planters as Partitions + Added Staircase	+ Panels on track system +Free Standing Element
Layout 4	+ Vertical Flexibility	+ Movable Furniture partitions + Wall Folding Bed + Added Staircase	+Free Standing Element

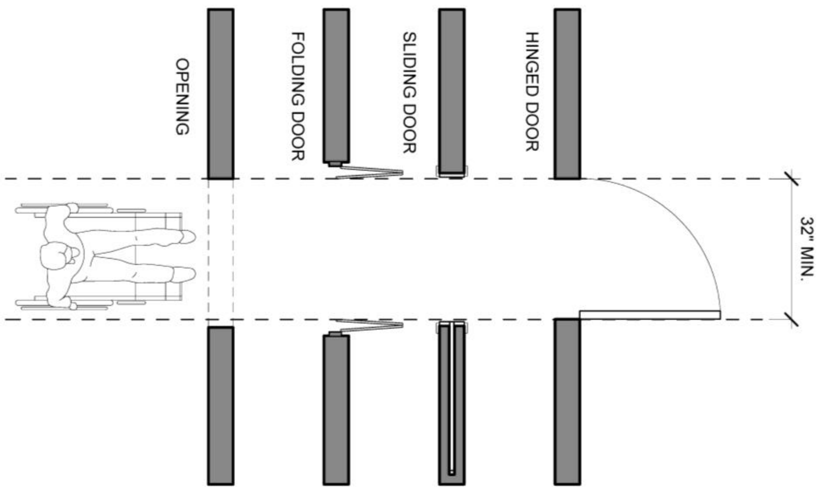


Figure 136: Doorway and Opening ADA Dimensions

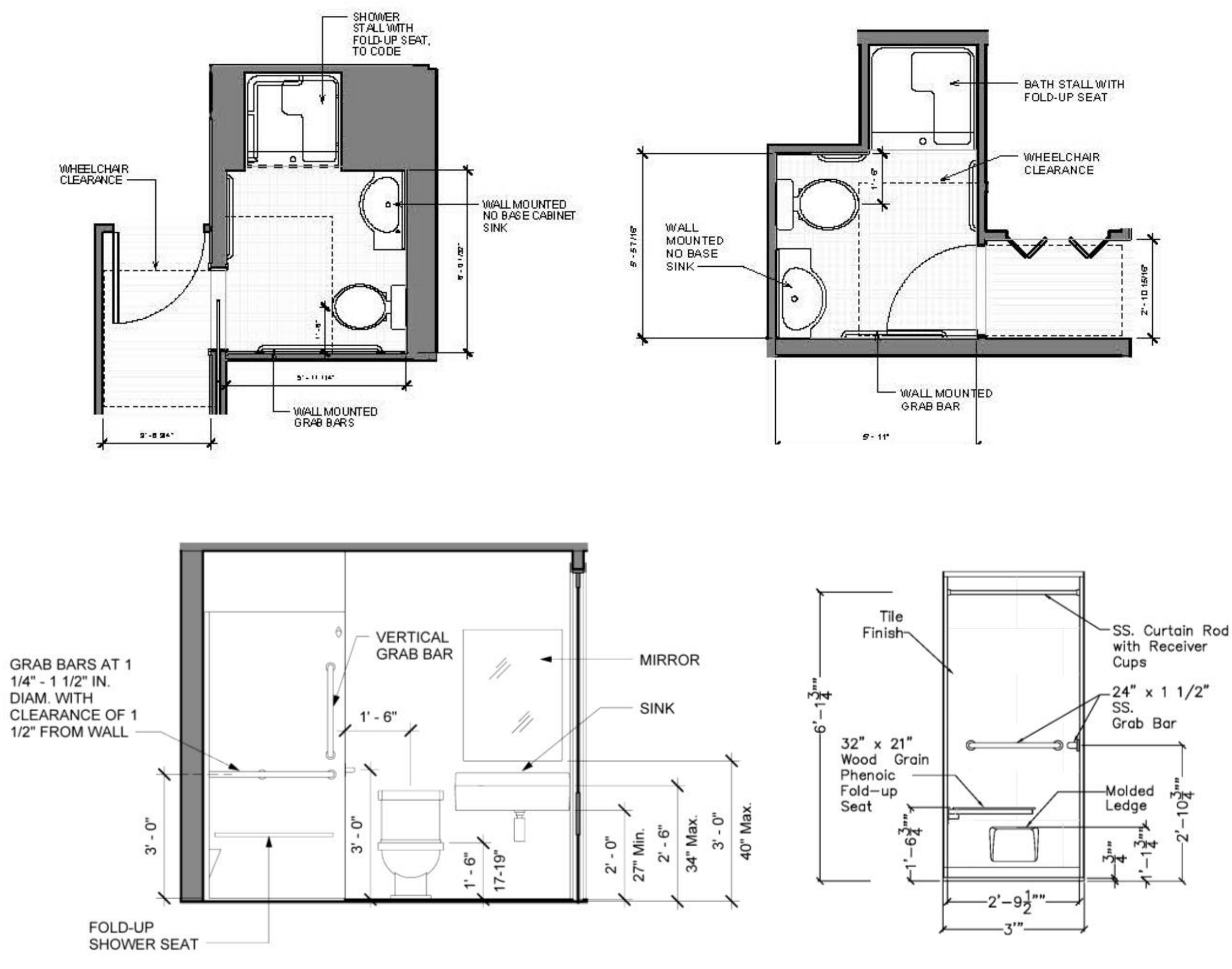


Figure 137: Bathroom Proper Dimensions

Universal design strategies just like prototype 1 were also applied in prototype 2. This includes, 32 in. wide doorway (Figure 136), Openings and corridor dimension requirements, bathroom dimension requirements and also ramps at the primary circulation on the sky lanai which connects the floors vertically.

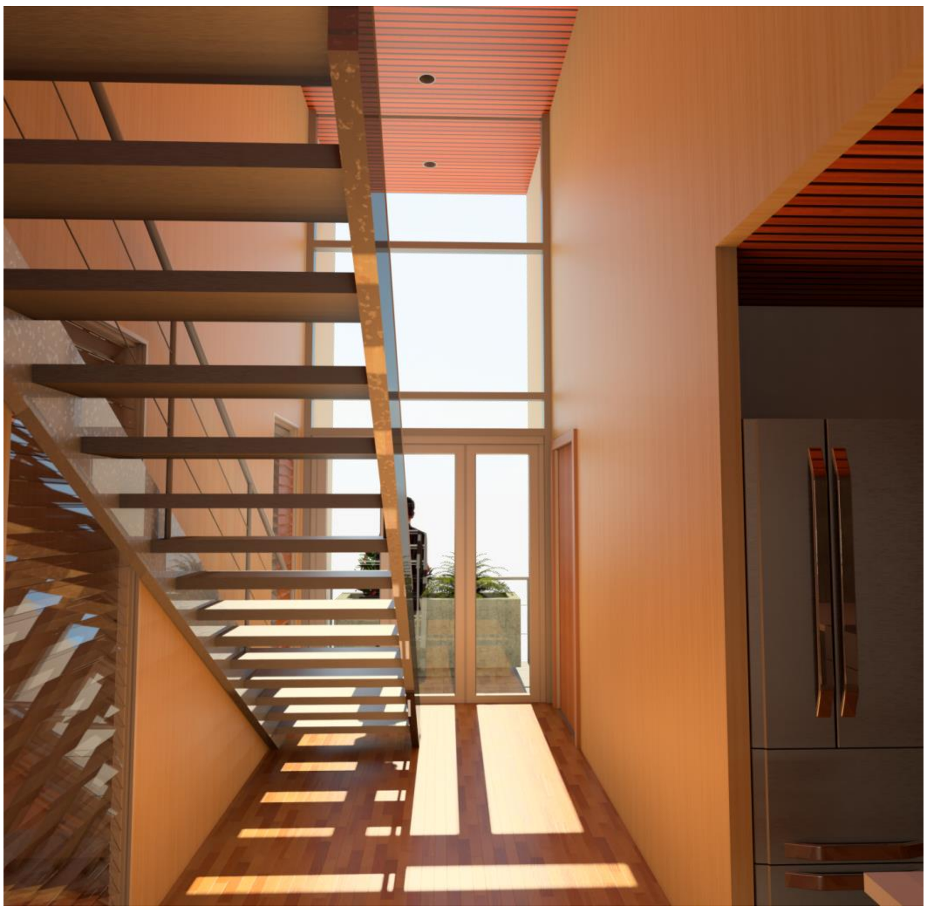


Figure 138: Prototype 2 Layout 2 Lanai and stairs rendering with the high ceiling view

Figure 139: Prototype 2 Layout 2 Exterior view of the stacked units

Prototype 2: Layout 1A Interior rendering of the unit with open folding walls.

Prototype 2: Layout 1B Interior rendering of the unit with enclosed folding walls.

Figure 140: Prototype 2 Layout 1A & 1B Interior Rendering

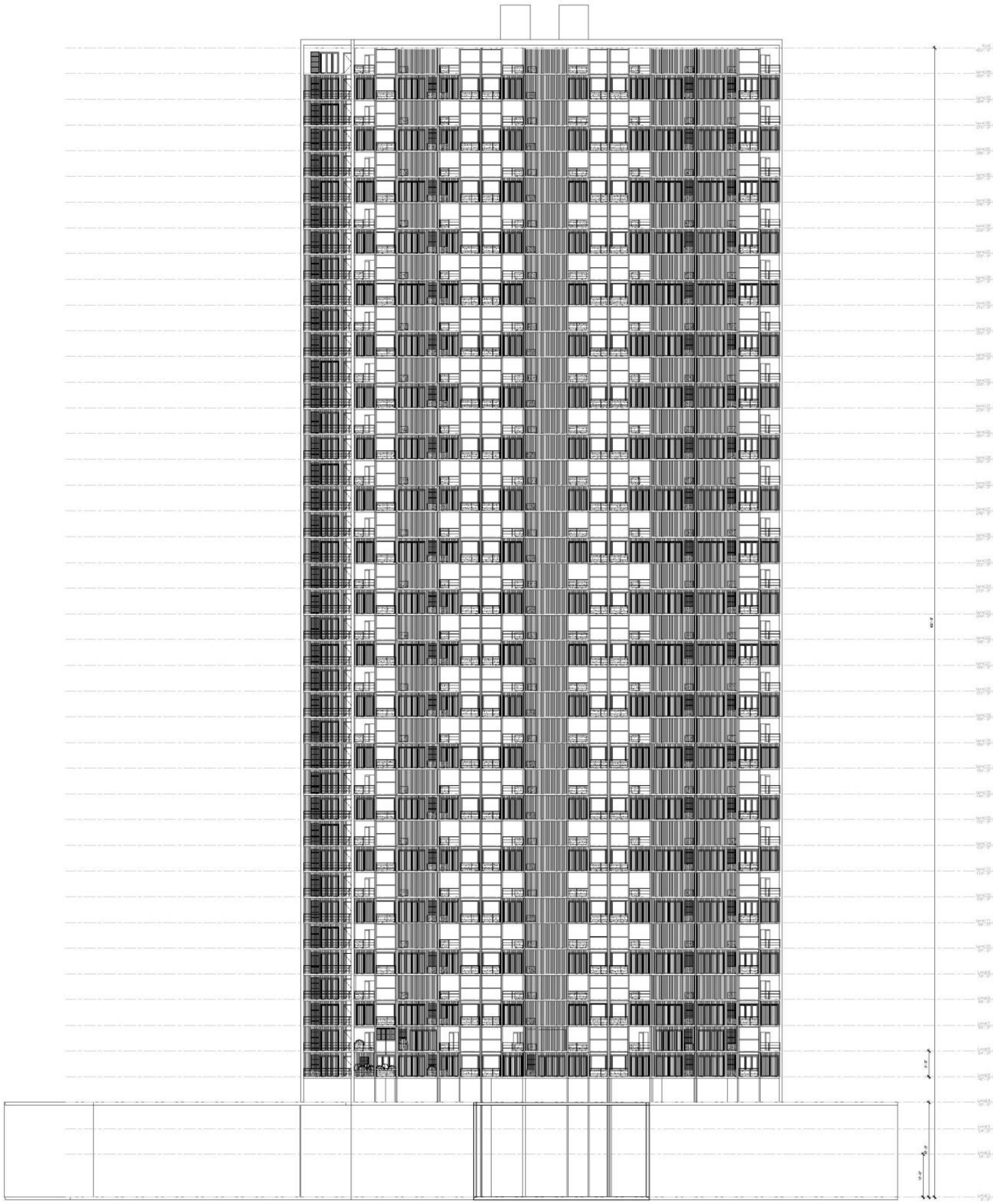


Figure 141: Prototype 2 South Elevation

Figure 142: Prototype 2 Exterior Rendering of the Sky Lanai

Building Rendering of Prototype 2

17.5 Overview

Overall prototype 1 and prototype 2 are designed with the goal of improving the indoor quality for the occupants, especially for the older adults. These are achieved through the optimization of the building performance through proper site and climate analysis which informs and influences the building form and proper systems.

The building mass was optimized to provide a more thermally comfortable indoor environment. Prototype 1 is composed with a view-corridor (south-east) oriented mass with a portion re-oriented to the south to reduce the direct solar impact and primarily to increase the cross ventilation of the building. Prototype 2 on the other hand, is composed with a south oriented mass which is the most optimal orientation for Hawaii[375]. The building elongated and slim form reduces the direct solar impact on the east and west façade and although the south façade receives a large amount of solar radiation during noon, can easily be shaded with simple overhangs.

The shading devices that were investigated for both prototype 1 and 2 includes the overhang, fins, combination, and louvers system. The comfort simulation for both prototypes indicates that the larger the depth of the shading device the better the performance; however the least effective system as shown is the fins shading device with very little difference in impact

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[375] Furuhashi, *Field Guide for Energy.* 23.

in relation to depth. Although a combination of both overhang and fins perform very well in reducing the discomfort hours and the direct solar impact especially as the depth of the shading device increases. The overhang and the louvers also show very effective results similar to the combined shading device. The depth of the shading devices could be larger, however for the purpose of the research is limited to 5ft to simply illustrate the significance of shading devices. Having larger shading depth does not necessarily translate to better performance as illustrated in Figure 126: Fins Shading Device and Orientation Comfort Analysis which shows that performance of the shade does not rely heavily on the depth itself but also the type and the configuration. An alternative solution is by increasing instead the density of the shading such as louvers (Figure 127) which is as effective, rather than increasing the depth of the shade.

The sky lanai is applied in both of the prototypes; it is an essential component of the building that promotes community interaction and social wellbeing. The sky lanai functions as a community space that allows for divers programs essential for the occupants such as garden spaces, fitness, lounge, social or activity programs. The flexibility of function that the sky lanai promotes is a beneficial characteristic for the occupants because it encourages social inclusiveness and activeness.

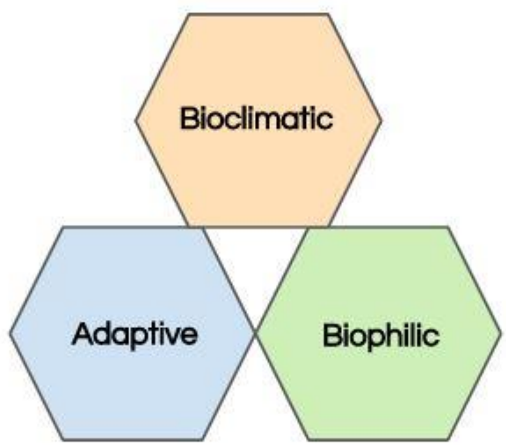
The sky lanai is also connected by the skip stop circulation system for both prototype, which is a circulation consist of elevators stopping only at every other floor and connecting the other levels with stairs or ramps. For both prototypes, the elevator stops exactly where the sky lanais are situated and ramps and stairs are included to connect the upper level. The benefits of having the skip stop circulation are that it promotes activeness and creates unplanned encounters between the residents.

The units designed in both prototypes focus on adaptability to respond to the changes and transformations of families, these are essential to creating a multigenerational households which is a healthier way of living especially for the older adults. The adaptability in the units are designed for both horizontal and vertical flexibility, which is achieved through flexible components and layouts including folding wall partitions, shelves and planters as partitions, folding wall beds, and also added stairs to connect units vertically. The strategies to provide flexibility are endless, but for the purpose of this research, the previously mentioned strategies are investigated and applied for its simplicity and ease of operability. The overall concept is to express the significance of adaptiveness in the housing units to adapt to the changes in a family.

Lastly, universal design was applied in design the units for both of the prototypes. This includes using proper dimensions and components to ensure safety and health overall, especially the mobility of the vulnerable occupants in this case people on wheelchairs and the older adults. Strategies used to achieve this include proper width of doors, openings, and passages, and proper bathroom layouts and dimensions. In addition, by applying these strategies, the environment can adapt to the changes of family structures easily without having to adjust the unit entirely to fit the needs of a specific occupant especially the fundamental elements such as corridors, path ways, and restrooms.

18. Design Evaluation

Design Principles



Precedent	Bioclimatic							
	Project Data/ Site Analysis	Form Giver	Transitional Space	Envelope	climate control system			
					high performance glazing	shading	natural ventilation	hybrid system
801 South St	na	na	na	na	Double pane glass windows and doors,	Lanai, Blinds	Operable windows, Lanai spaces	Split air condition system
Ke kilohana	Wind analysis	na	Sky courts	na	na	Blinds	Sky courts	na
Prototype 1	Solar Impact and Daylight analysis Wind Flow Analysis Neighboring Buildings Analysis	Solar Exposure Natural Ventilation	Sky Court/Lanai	Building Screen Shading Device	na	Brise-soleil Lanai Building Screen	Building Orientation Sky Courts High Ceilings	Scheduled system
Prototype 1	Solar Impact and Daylight analysis Wind Flow Analysis Neighboring Buildings Analysis	Solar Exposure Natural Ventilation	Sky Court/Lanai	Building Screen Shading Device	na	Brise-soleil Lanai Building Screen	Building Orientation Sky Courts High Ceilings	Schedule for hybrid cooling system

Precedent	Adaptive			Biophilic			
	Building level	Unit level	Room level	Environmental factor	Natural Shapes	Light	Space
801 South St	na	na	lanai space	Orientation to preserve view access, 100% of tower parallel to South st façade, site Landscape, Street trees	na	Daylighting	Diversity of space volume and size
Ke kilohana	na	Light framed partitions	Light framed partitions	Orientation to preserve view access, parallel to Ward avenue 38 degrees west of south, Sky courts, Landscape view, Street trees	na	Daylighting	Diversity of space volume and size
Prototype 1	na	Vertical and Horizontal Expansion	Light Framed Partitions Movable/Folding/Sliding Partitions Furniture as Partitions Open Floor Space	Building Orientation to preserve View, Optimize for Passive System Lanai Spaces for Interaction with Nature Sky Courts with Gardens Natural Ventilation	Curved Forms	Daylighting	Diversity of spaces, function and volume
Prototype 1	na	Vertical and Horizontal Expansion	Light Framed Partitions Movable/Folding/Sliding Partitions Furniture as Partitions Open Floor Space	Building Orientation to preserve View, Optimize for Passive System Lanai Spaces for Interaction with Nature Sky Courts with Gardens Natural Ventilation	Curved Forms	Daylighting	Diversity of spaces, function and volume

Table 5: Design Principles Matrix Evaluation

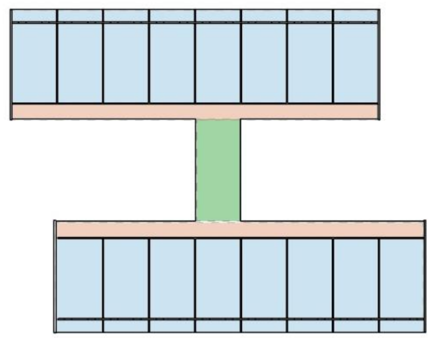
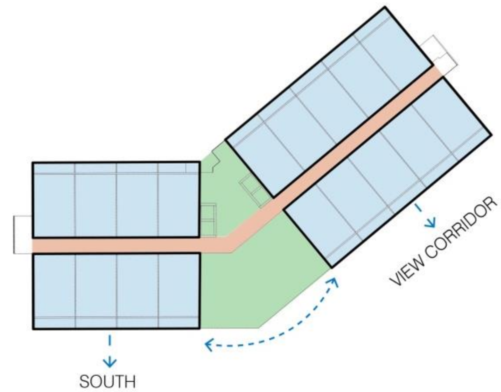
	
Prototype 1	**Prototype 1**
Advantages • Less obstruction to view • Larger Sky Lanai	Advantages • Orientation is optimized for less solar heat gains and maximized ventilation • Units extending from one facade to the other offers a better opportunity for natural ventilation • Improved Daylighting due to openings from each end of the unit. • Shading device perform better with orientation
Disadvantages • More Surfaces/facades; more exposure to sunlight • Orientation receives more solar heat gain • Orientation limits natural ventilation • Double Loaded Corridor Limits Cross ventilation	Disadvantages • Shaded Sky Lanais could impact the need of sunlight for garden. • One building could obstruct a view

Table 6: Prototypes Design Asessment

Overall prototype 1 and prototype 2 designs acquire the characteristics and qualities that the proposed design criteria entail (Table 5: Design Principles Matrix). In comparison to the existing precedence, the prototypes encompass more qualities that the design principle promotes which in turn improves the performance of the building and increases the quality of the environment for the occupants.

Bioclimatic design is achieved through proper site and micro-climate analysis to better understand and inform the process of design. The climate condition on site influenced significantly, the optimization of the building form and layout to improve the overall building performance in providing a comfortable indoor environment. This includes building simulation that was conducted in order to optimize the building design to enhance passive systems such as natural ventilation for cooling and assessing the most effective shading system to reduce direct solar impact for a more comfortable indoor temperature. In addition, sky lanais were incorporated into the design to create open spaces that enhances the flow of wind through the building. Moreover, hybrid cooling system can be achieved once the building performance is optimized, the hybrid system is based on a schedule of climate conditions particularly temperature and humidity. The hybrid system utilizes both passive and active systems, with a larger dependency on the performance of the passive systems. The mechanical systems respond to the indoor and outdoor temperature and humidity, responding to unbearable climates such as high heat events.

The adaptive design principle is achieved through flexible strategies in both the unit and the room level. This includes flexible elements that are operable such as folding wall partitions, folding doors, free-standing shelves as partitions, folding wall bed, planters as partitions, connected lanais and placement of stairs to connect units vertically.

Finally biophilic design is attained in the building design through elements such as building orientation to maximize view of landscape, optimizing passive systems which allow natural elements within the building like natural ventilation and daylighting. The sky lanais are elements that provide both direct and indirect interaction between the residents and the natural environment through visual connection of landscapes, exposure to wind and the sun, and also direct interaction with plants through gardening. Moreover, the flexibility of the space promotes diverse volumes and layouts of spaces which is an essential characteristic of biophilic design.

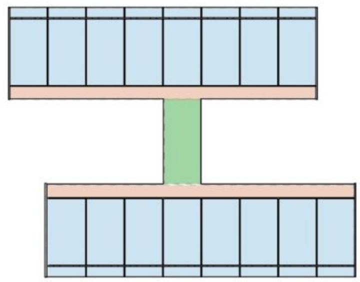
Level of Healthiness

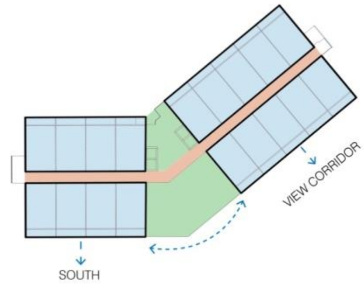
Blue Zone Elements

+ MOVE NATURALLY

+ RIGHT OUTLOOK
- + Purpose Now
- + Downshift

+ BELONGING
- + Right Tribe
- + Community
- + Loved Ones First





	Prototype 1	Prototype 1
MOVE NATURALLY	• Comfortable environment • Full control of living environment • Skip-stop elevator	• Comfortable environment • Full control of living environment • Skip-stop elevator
RIGHT OUTLOOK + Purpose Now + Downshift	• Multigenerational living • Sky lanais for gardening • Private Lanai • Interaction with nature; restorative value	• Multigenerational living • Sky lanais for gardening • Private Lanai • Interaction with nature; restorative value
BELONGING + Right Tribe + Community + Loved Ones First	• Intergenerational community • Multigenerational living • Socially inclusive • Community spaces • Accidental interaction • Sense of Ownership	• Intergenerational community • Multigenerational living • Socially inclusive • Community spaces • Accidental interaction • Sense of Ownership

Table 7: Blue Zone Elements Comparison

To measure the level of healthiness, the prototypes are compared to the blue zone elements. The assessment indicates that the prototypes, acquire qualities in its built environment similar characteristics as the Blue Zone regions which promotes healthy lifestyle. Of the five Blue Zone Elements, three were the most relevant to the design criteria of the prototypes which include, moving naturally, having the right outlook and belonging. Both prototypes achieve these qualities evenly.

Moving naturally is promoted through the overall comfort of the environment as well as providing control of the living space to the occupants. In addition activeness is promoted by providing community spaces such as the sky lanai and also the result of applying the skip-stop circulation both of which encourages the residents to move and socialize. Furthermore, the adaptation of universal design enhances the ease of movement especially for the vulnerable occupants.

Having the right outlook which includes the purpose of living now and a place for downshift is achieved through the qualities of the multigenerational living which improves the social relationship of the older adults with their families creating self-purpose or just like the Japanese belief in having an *ikigai (purpose for living)*. Also, by incorporating community spaces like the sky lanai, space for interaction with nature is created, such as gardens or exposure to the natural elements and views of the landscape.

Lastly, the qualities of belonging which includes being in the right tribe, being part of a larger community, and the value of putting loved ones first are achieved through the influences of the multigenerational living. Living in a multigenerational household provides a better living situation particularly for older adults because it improves their relationship with their families, which is a definite characteristic of being in a right tribe. In addition, the mixed used programming, intergenerational residences, the sky lanais and the skip-stop circulation are all essential building elements which promote social inclusiveness; allowing the occupants to interact naturally. Furthermore, the flexibility of the units promotes a sense of ownership to the occupants which enhances the quality in the feeling of belonging.

19. Conclusion

The aging and growing population has major influences over the way the built environment is being shaped. In Hawaiʻi particularly, there is a demand for affordable housing because of the high cost of living and the inadequate household income, as well as the aging and increasing population that is only aggravating the situation, which impacts the well-being of the people especially the elderly. The high cost of housing and long-term care services brings burden to many families, which often warrants finding alternative solutions. Multigenerational homes become a desirable option because of their overall benefits that encompass affordability and social advantages. However, the lack of support from the politics limits the amount of multigenerational homes being constructed therefore further limiting the housing options for the population, particularly impacting the elderly. Consequently, this leaves the older adults in housing environments that are detrimental to their health. Additionally, the changes in the climate intensify the impacts that the indoor environment has to their wellbeing, and already a vulnerable group of the population, this makes them further at risk concerning their thermal comfort and the physical impacts it entails.

The high-rise residential is a housing option that is becoming a more preferred typology in Honolulu with multiple projects currently being constructed or planned, particularly because of the financial benefits that it offers for both the developer and the occupants. Many of these residential high-rises are becoming more intergenerational, primarily because they provide an environment that is socially inclusive, which promotes a healthier lifestyle for the occupants, an ideal environment for older adults. On the other hand, current residential high-rises in Honolulu more than likely, do not have the qualities that are essential to the health of older adults such as responsiveness to the climate, flexibility to adapt to demographic changes, socially inclusive spaces, and limited interaction with nature.

In response to this issue, a design criterion that focuses on the needs and the health of the population particularly the older adults is necessary. This consists of three design principles that are applied to a high-rise architecture typology, which includes bioclimatic, adaptive and biophilic design. These three embody qualities that were inspired by characteristics gathered from studies and precedents that promote wellbeing and a comfortable indoor environment.

Bioclimatic design is the fundamental principle to building performance, which provides an indoor environment that is thermally comfortable for occupants through the use of responsive strategies, such as natural ventilation for cooling, shading devices to reduce solar impacts, or the use of daylighting. In order to achieve a responsive architecture, it is important to have the proper knowledge and assessment of the site and climate condition, to inform and guide the design process for a more optimized building form and systems. In addition to further enhancing the building performance, building simulation should be conducted to analyze and investigate the most effective design solutions for the building. The objective for bioclimatic design is to optimize the passive strategies in providing thermal comfort rather than relying fully on mechanical systems. Passive deign strategies encourage adaptive thermal comfort, which gives occupants the full control of their environments to adapt to climatic changes and simultaneously increase their range of acceptable thermal conditions. Therefore, occupants are able to adjust the environment to respond to certain conditions as well as being able to accept a higher range of temperature especially with proper natural ventilation and/or with the help of mechanical ventilation such as ceiling fans.

The key factor of adaptive design is its qualities that promote aging in place and multigenerational living, which improve the social inclusiveness and activeness of the community, key elements to well-being and longevity.

Adaptive strategies applied in this research include flexible strategies, such as folding wall partitions, shelves and planters as partitions, folding wall furniture, added stairs, and connected lanais, all of which permits horizontal and vertical flexibility. Adaptive design is essential to promoting multigenerational living because it enables the occupants to adapt the environment to the changes of the household. In addition, universal design strategies are applied in the design process to reinforce the ability for the architecture to adapt for all users, especially for vulnerable occupants. Universal design strategies include proper dimensions of doorways, passages, corridors, bathroom layout and components, as well as incorporating ramps for ease of access.

Biophilic design principle is achieved through the integration of nature into the architecture, which is an essential environmental quality in promoting healthier lives through restorative values, which reduces psychological stress, acquired in both direct and indirect interaction between the occupants and nature. Biophilic qualities are prominent in the qualities of the bioclimatic design; the optimization of passive strategies in itself, integrates the outdoor natural environment into the indoor spaces through natural ventilation and daylighting. Characteristics that are biophilic includes the application of the unit lanais and the central community sky lanais, which contain garden spaces, exposure to the outdoor environment, and view of the landscape. In addition, the sky lanais provide multi-function community spaces, which enhance the social quality of the building, and encourage the residents to be more interactive with one another. Similarly, the skip-stop circulation connecting to the sky lanais also encourages the users to move which is beneficial to the occupant's health.

The outcome of the design principle is not the ultimate solution to longevity and good health. In fact, there qualities that are overlooked such as promoting healthier diet or enriching occupant's participation in community activities. However the qualities that the design principles entail are similar to the qualities that healthy environments possess, such as the blue zone regions. The design principles translate environmental characteristics similar to the blue zone regions, which supports in large aspect the blue zone elements described by Beuttner as the Power 9. The design principle relates to three of the elements, including moving naturally, having the right outlook, and belonging to a community.

Moving naturally is achieved through the design principles by providing a comfortable environment, giving control of the layout to the occupants, the skip stop circulation, which encourages the users to move, universal design thus providing a safe and easy spatial transitions, and lastly, community spaces that encourages the residents to be active.

Having the right outlook, including having purpose for living and a space for downshift, are achieved by the design principles through the integration of multigenerational living and private and public spaces. The multigenerational household improves the relationship for families and promotes constant interaction, which is a healthy outcome for the occupants, especially for older adults who gains personal motivation or purpose to their lives for this reason similar to the Okinawans with *ikigai*. Likewise, the community spaces provide the opportunity for diverse programs to take place, which may also motivate and create a purpose for the occupants to wake up in the morning. The unit lanais and the central sky lanais offer both private and public spaces that give the occupants a setting conductive to downshift and self-reflection.

Belonging to a community is the last element of the blue zone that is addressed by the design criteria. Belonging further encompasses the virtues of being in the right tribe and putting loved ones first. The design principles simulate these qualities through elements, such as the sky lanais which are responsible for promoting community interaction, these spaces gives the residents especially older adults. For older adults, these spaces could be utilized for gardening as pastime. Having community spaces allows the occupants to be part of a community within the building. Moreover, the multigenerational household defines clearly the quality of putting loved ones first, by allowing families to live with extended members especially the older adults.

In summary, the design principles are expected to improve the quality of the built environment which consequently improves the quality of life for the occupants, especially the aging population. As described by Buettner, "longevity is not a choice that the people of the blue zone make. Instead it happened naturally to them because of the qualities of the lifestyle and the environment that they live in. This is contrary to common belief that the condition of the human health is based principally on behavioral factors."[376, 377] Instead, as Buettner would say "it was the residue of the environment" that these blue zone communities lived in. Therefore, if we want to have a population characterized by a healthier lifestyle and enhanced longevity, then as architects, urban designers, planners, policy makers, and other creators of the built environment, we have to think about the Impacts that the physical space that we design have towards the health of people.

In Hawaii the needs should be the underlying influence of development which includes affordability and most importantly health for the aging population. The innovation in this research lies specifically in the integration of health directed elements that are translated into a design criterion, which can be easily applied in the design process of residential high-rises by architects or any design profession. It is essential for designers of the built environment to think about the longevity of the buildings not only structurally but also functionally to adapt to changes that occur in the

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[376] "Dan Buettner: Creating Healthy Communities." YouTube video, 46:28, lecture on May 3, 2016, posted by "SMUVideo," May 24, 2016. https://www.youtube.com/watch?v=2pT966VCf_k&t=2455s.

[377] "The Determinants of Health." *World Health Organization*. Accessed December 07, 2016. http://www.who.int/hia/evidence/doh/en/.

society. This, not only eliminates the need for users to purchase a new home when changes in the household occurs and for developers to reconstruct the building to meet new standards and trends, but it also allows for aging in place and promotes multigenerational living. In addition the experience of the users should be the primary concern for the designers; therefore site conditions should be assessed and analyzed during the design process, to inform the designers in making design decisions. The concept behind prototype 1and 2 is to demonstrate the flexibility and practicality of the design criteria, that although building optimization and performance should be the key influence of the building form, it is still applicable even when regulations and zonings are taken into account and the results are still rewarding.

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